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Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

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Journal of the
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HYDROLOGICAL ASPECTS OF RADIOACTIVE WASTE DISPOSAL

William H. Bierschenk,¹ J. M. ASCE
(Proc. Paper 1835)

ABSTRACT

Geologic and hydrologic data have made it possible to reasonably predict the behavior of low-level radioactive wastes discharged to ground at Hanford. It is emphasized that at no time in the plant's history has the underground movement of radioactive wastes resulted in detectable amounts reaching points of public access.

INTRODUCTION

Two important environmental elements affecting site selection for atomic energy plants are the geology and hydrology of the area.⁽¹⁾ Furthermore, under known conditions, the phenomena connected with ground-water motion may be used to lessen the hazards incidental to the wastes of the atomic energy industry.⁽²⁾ The purpose of this paper then, is to report on the scope of ground-water hydrology investigations at Hanford required for safe ground disposal of low-level radioactive wastes.

The Hanford Works lies adjacent to the Columbia River directly north of the confluence with the Yakima River in the south-central part of Washington. The AEC reservation is approximately 620 square miles in area, and within nearly all this area the earth materials are sufficiently permeable that their contained water is essentially unconfined and drains down to a base level adjusted to that of the Columbia River. Thus the zone naturally saturated with water is roughly from 200 to 300 feet beneath land surface in the north-central part of the area south of Gable Mountain. This zone is largely in the well-bedded lacustrine silts, sands, and local beds of clay and gravel of the Ringold formation, and to a lesser extent in the coarse-grained glacio-fluviatile deposits and in the Yakima basalts.⁽³⁾ Subsequent to plant start up,

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appreciable changes have been made in the regional body of unconfined ground water with the result that the water table now occurs in the more permeable glacio-fluviatile sediments over a large part of the area.⁽⁴⁾

The total volume of all effluents released to ground from various chemical processing plants during the period January 1944 through June 1957 amounts to about 29.6 billion gallons, of which 26.7 billion gallons was process cooling water and 2.9 billion gallons was low-level radioactive wastes. Although some of the liquid is dissipated to the atmosphere through evapotranspiration and some is retained in the pores of the sediments in the zone of aeration, most percolates down to the water table and enters the zone of saturation.

With the addition of such large volumes of liquids to the ground-water reservoirs underlying radioactive waste disposal sites, prediction of the behavior of the ground water becomes difficult inasmuch as increased hydraulic gradients and altered rates and directions of ground-water movements are imposed. Thus it is necessary to obtain basic hydrologic data which define areas of highly permeable sediments and which depict the changes in the water table. These changes are evident from a series of maps which show the shape and position of the water table by contour lines at successive stages of Hanford operations.

Ground-Water Contours

The ground-water contour maps are based on the measured altitude of the water surface in a pattern of wells (at present numbering 117), the contour lines representing lines of equal altitude on the water table expressed in feet above mean sea level. The greatest number of these wells monitor two ground-water mounds, permitting rather accurate contouring in these locations. The relatively few data available for those areas lying north of Gable Mountain and immediately northeast of Rattlesnake Hills require liberal interpretation and generalization, and there may be substantial deviation, at least in detail, from the shape and position of the contours as shown.

Fluctuations of the Water Table

The Hanford region lies in the rain shadow of the Cascade Mountains. It has an average annual rainfall of 6.29 inches, little or none of which penetrates to the water table beneath plant areas where the depth to water is as much as 350 feet. Thus, the source of ground water is precipitation upon Rattlesnake Hills to the southwest (Fig. 1) and (not shown) upon Yakima Ridge to the west. The water percolates underground near the base of the highlands and moves down gradient in a general northeastward and eastward direction toward the Columbia River. The northeasterly movement of ground water is somewhat impeded by Gable Mountain and its extensions, and by a buried basalt ridge that roughly parallels Rattlesnake Hills at a distance of about three miles and which locally rises above the water table. Adjacent to, and from one to three miles distant from the river, the regional body of ground water enters a zone in which both direction and rate of movement varies widely, depending on fluctuations of river stage. Discharge of ground water from the area is thus by percolation into the river so long as the river is not at a high stage.

Irregularities in the shape and slope of the water table, shown on following figures, are caused largely by (a) recharge of aquifers by plant effluents,

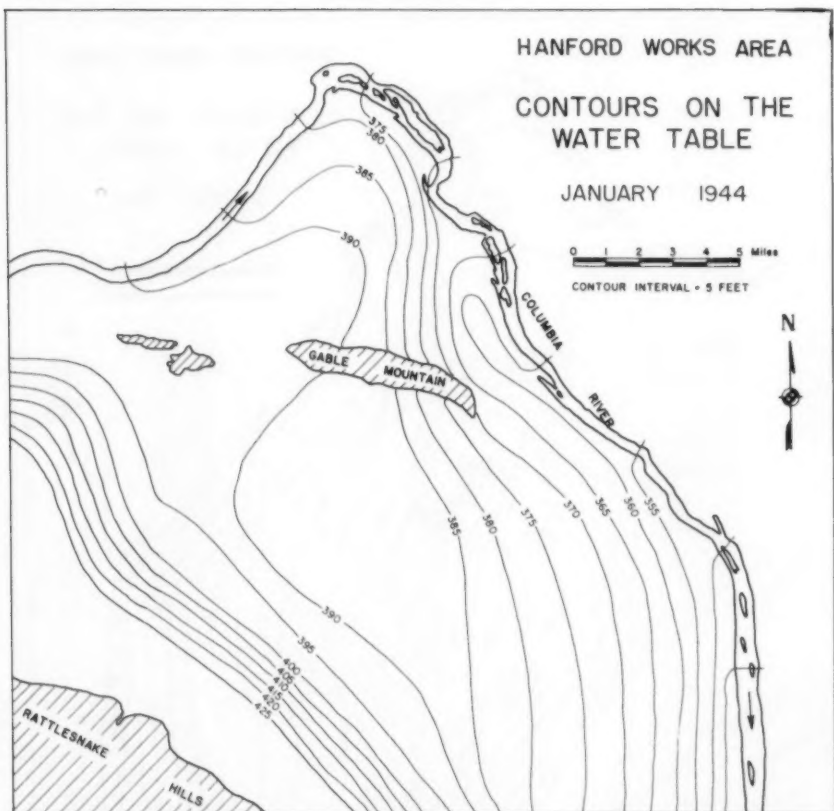


Figure 1

(b) local differences in the thickness and permeability of the deposits, and (c) river-level fluctuations.

Fig. 1 shows the contours on the water table as they probably occurred prior to plant operation. The contours are based on scanty data, but nevertheless the generalizations appear not unreasonable. Figs. 2 through 6 show the ground-water contours at subsequent stages of operations.⁽⁴⁾ The three wells shown on these figures (wells A, B, and C) are used for reference inasmuch as they are located near the several open disposal swamps, and water-level data for them probably best represent fluctuations of the known apex altitudes of the ground-water mounds.

Fig. 2 shows the shape and position of the water table after about seven years of plant operation. The two principal features shown are an eastern and a western ground-water mound which had been built up as the result of infiltration of plant effluents. The two mounds as shown were formed by approximately equal volumes of effluent; roughly 5.5 billion gallons to both areas. Consequently, water levels beneath the eastern area rose an estimated maximum of about 15 feet, or from an elevation of about 390 feet above mean

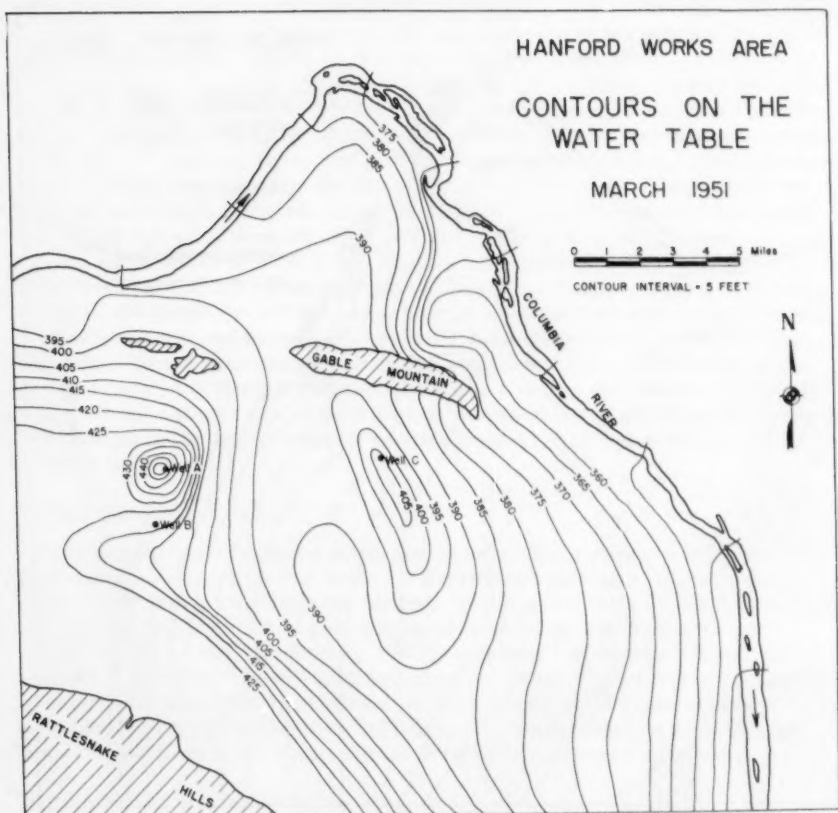


Figure 2

sea level to over 405 feet; and levels beneath the western area rose about 55 feet, or from an elevation of about 395 feet to about 450 feet.

The mounds significantly altered the natural directions and rates of ground-water movement. For example, whereas the natural eastward gradient beneath the eastern and western mounds ranged from about 3 to 6 feet per mile, respectively (Fig. 1), the mounds locally reversed the gradient such that ground water flowed in all directions and, under the influence of a 20-foot per mile average gradient in the west and as much as a 10-foot per mile average gradient in the east, at velocities several times greater than those existing previously. At this time, based on extremely limited data, the average velocities were estimated to range from less than 1 to about 5 feet per day.

During the next six years, the ground-water mounds fluctuated depending on varying operational procedures, such as changes in rate and volume of effluents and locations of disposal facilities. In general, the eastern mound declined about 10 feet between 1951 (Fig. 2) and 1955 (Fig. 4) and then rapidly reestablished itself in 1956 and 1957 (Figs. 5 and 6) by rising more than 15 feet to an elevation of over 415 feet.

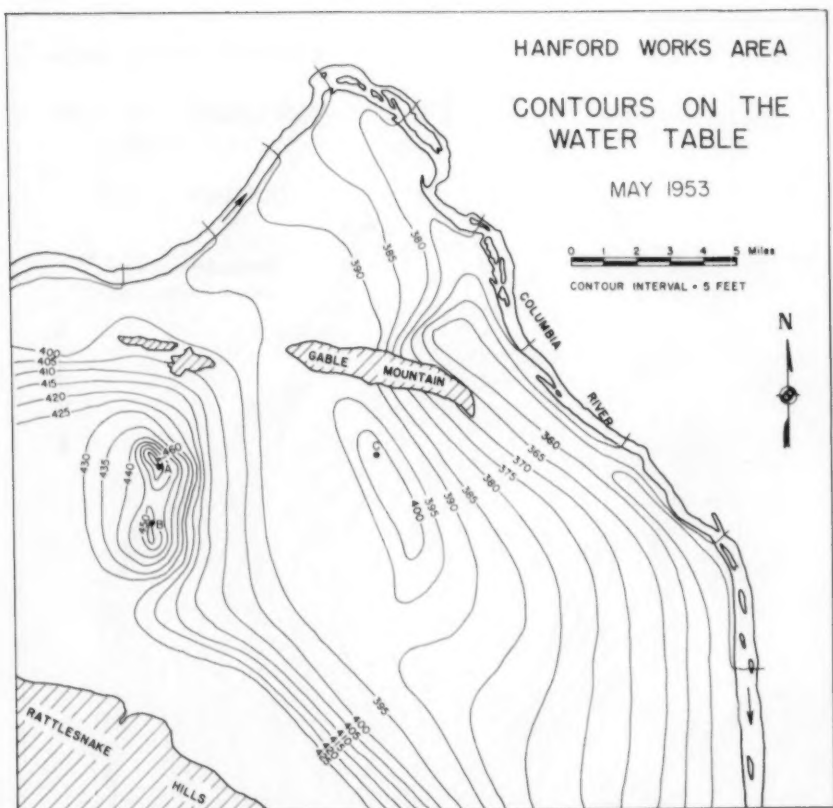


Figure 3

By 1953 (Fig. 3) the western ground-water mound developed twin peaks as the result of disposal to facilities in both the north and south of the area. The water level in well A at the north rose 10 feet between 1951 and 1953 to an elevation of over 460 feet, and to the south in well B the water level rose more than 30 feet to an elevation of about 455 feet. Subsequently, the several components of the mound joined to form a single apex at well A (Fig. 4), which stood more than 90 feet higher than the inferred pre-plant level. During 1956 the apex of the western mound shifted southward (Fig. 5) consequent to operational changes, and with the result that by June 1957 (Fig. 6) the water level in well B stood at an elevation of over 475 feet, about 80 feet higher than the pre-plant level and some 10 feet higher than the level in well A.

Porosity Determinations

The water table has thus risen substantially within a major part of the Hanford Works area, beneath and adjacent to the several processing plants. Fig. 7 shows the extent and amount of this inferred rise, by lines of equal thickness on the zone between the water table of June 1957 (Fig. 6) and the

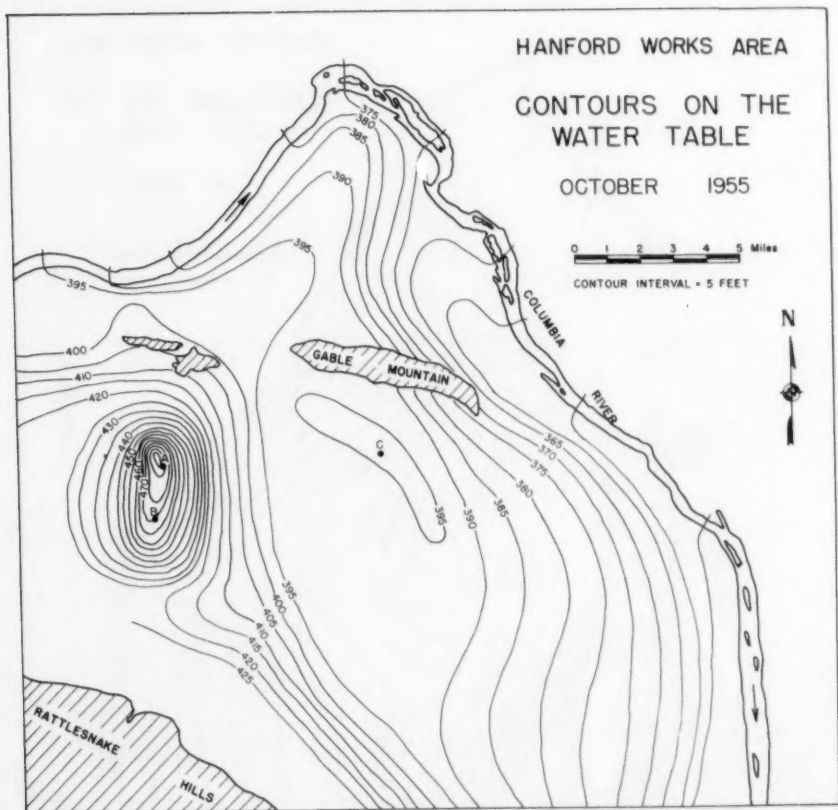


Figure 4

water table as inferred to have existed before Hanford operations began (Fig. 1). The total volume of sediments affected by the rise in water levels was determined by graphical integration with a planimeter and measured approximately 62 billion cubic feet. Assuming all the process water wasted to ground since 1944 is still in the zone depicted (none discharged to the Columbia River), the above volume of sediments has been saturated with about 30 billion gallons of water, or about 4 billion cubic feet. Thus, the average wetted porosity of the sediments is about 6.4 per cent. Previous estimates of this value (effective porosity), derived by personnel of the U. S. Geological Survey for less expansive areas, averaged about 8.3 per cent.

Movement of Ground Water

As Fig. 6 indicates, the present pattern of ground-water movement underlying Hanford Works has changed fundamentally during the 13 years of plant operation, owing to concurrent changes in water-table form. In brief, the zone saturated by infiltrated waste effluents creates a ground-water divide, roughly concave to the south and enclosing disposal sites on the west, north,

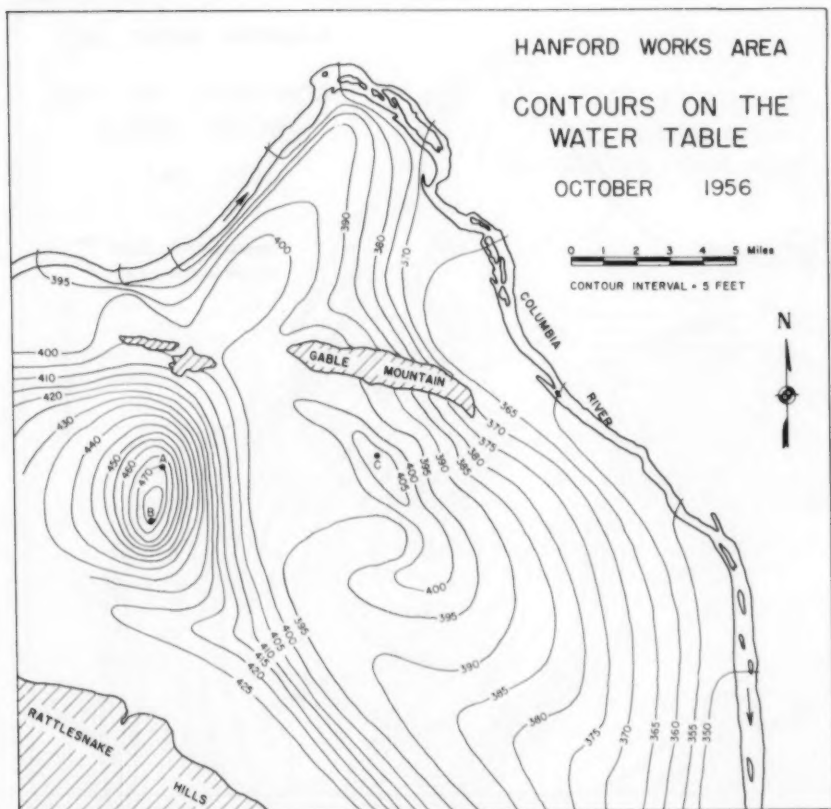


Figure 5

and east. From the northern or outer flank of this divide, the artificially recharged water largely moves radially northeastward. From the southern or inner flank of the divide, the infiltrated wastes converge and move generally southward then southeastward in a relatively narrow band. Extrapolating this movement to the future indicates a junction with the Columbia River about 10-15 miles north of the confluence with Yakima River, but only after a significant lapse of time. (The Yakima River enters the Columbia River from the southwest, the confluence being 12 miles south of the southern border of the figures.)

Owing to these artificial elements in the pattern of movement, ground water which enters the area naturally, along the valley at the base of Rattlesnake Hills and Yakima Ridge, presumably now can pass to the Columbia River only upstream from the western ground-water mound and downstream from a point about 10 miles north of the Yakima River. It is now excluded from the intervening reach of the river.

The directions of movement in the regional body of unconfined ground water, here described, are those which would be taken currently by any radioactive waste products infiltrating to the water table. Trace amounts of short-

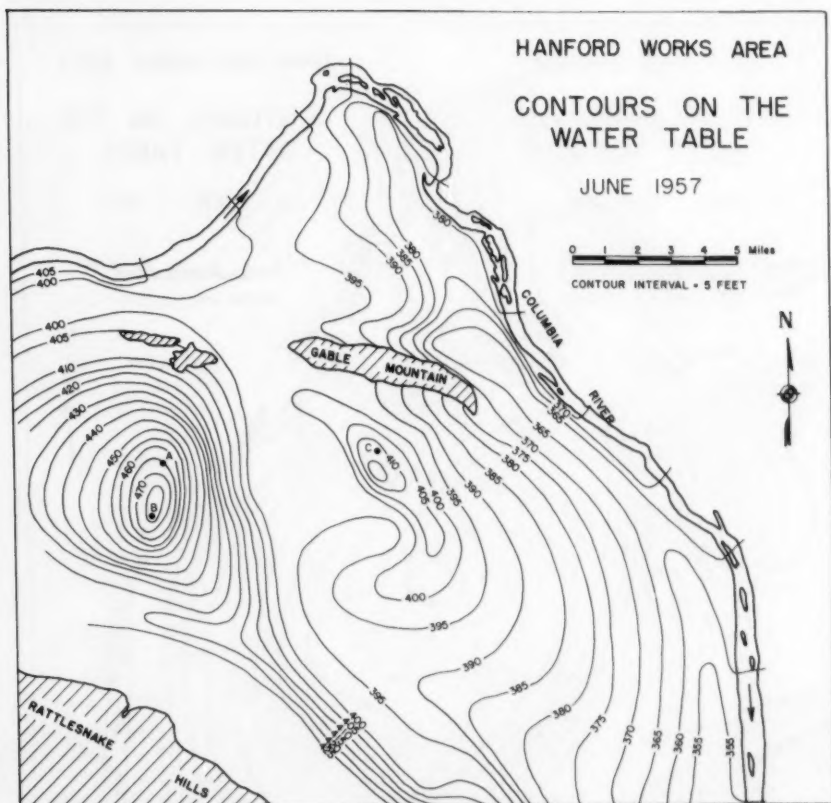


Figure 6

lived radioisotopes are occasionally detected in the ground water in the vicinity of the disposal areas, but the material permitted to enter the ground water is deliberately restricted to that having a radioactive life that is short compared to the time it takes to move to a point of public access. The site of infiltration therefore determines the potential direction taken by the segment of the ground-water body "contaminated" by that infiltration. Thus, whereas the ground water which exists between the two current ground-water mounds and which locally contains trace amounts of shorter-lived radioactive material inferentially is now essentially immobile, it potentially will move southward and southeastward toward the Columbia River, reaching there only after a significant decay period. Movement to the southeast actually started early in 1956. At that time water samples from wells as much as 8 miles to the southeast showed trace concentrations in the order of $1 \times 10^{-7} \mu\text{c/ml}$ of radioactive materials (probably chiefly ruthenium - 106) apparently moving with velocities in the order of hundreds of feet per day. The movement probably was initiated by the subsidence of the eastern ground-water mound which presumably had blocked the flow to the southeast (see Fig. 4). These high velocities

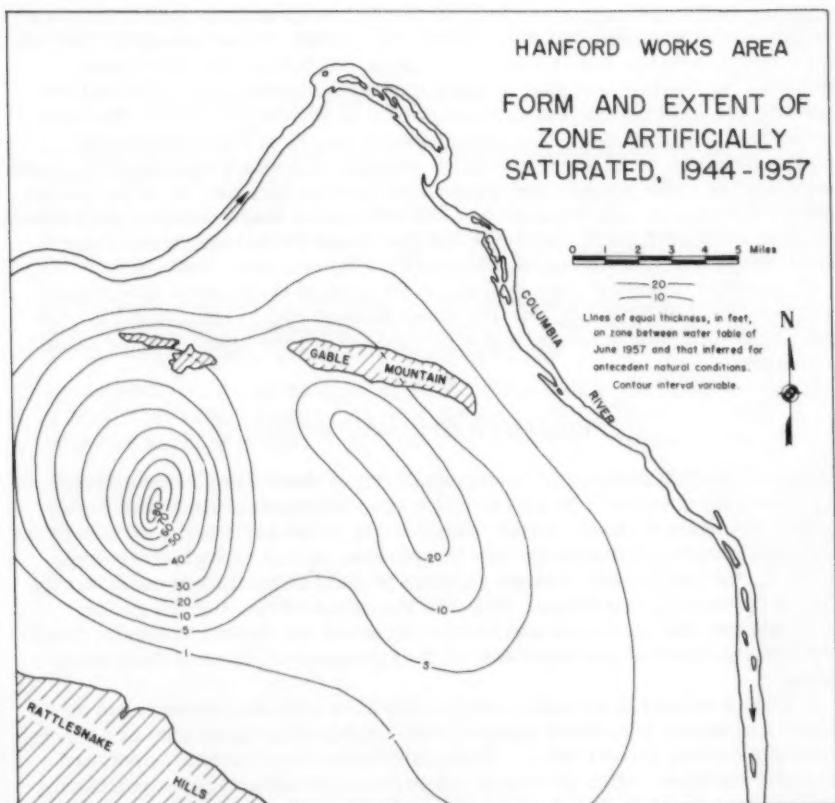


Figure 7

were later confirmed by a large-scale fluorescein tracer test in the area. This test showed detectable amounts of fluorescein in observation wells 8800 feet south-southwest and 8500 feet southeast of a treated well, representing average linear velocities of 350 and 770 feet per day, respectively. The restoration of the eastern mound (Figs. 5 and 6) has again blocked the southeastward movement of contamination.

Hydraulic Characteristics of Sediments

Areas or channels of highly permeable glacio-fluviatile sediments containing rapidly moving ground water have been identified extending eastward along the northern and southern flanks of Gable Mountain, and extending southeastward from near the disposal areas toward the Columbia River.

North of Gable Mountain, determinations of the hydraulic characteristics of the aquifers by drawdown and recovery tests, by estimates from specific capacity tests, and by use of the sinusoidal head-fluctuation method,⁽⁵⁾ gave

transmissibilities* ranging roughly from 300,000 to 400,000 gpd/ft and permeabilities averaging about 13,000 gpd/ft². A number of tracer tests at one site indicated an average linear velocity of about 170 ft/day. South of Gable Mountain, an aquifer test gave a coefficient of transmissibility of 3,000,000 gpd/ft and a field coefficient of permeability of 66,700 gpd/ft².⁽³⁾ The high permeabilities southeast of the processing areas, first suggested by the elongation of the eastern ground-water mound and then confirmed by the rapid movement of radioisotopes and fluorescein tracers (see above), were further defined by two pumping tests in the area which gave coefficients of transmissibility of 1,850,000 gpd/ft and 2,900,000 gpd/ft and field coefficients of permeability of 26,500 gpd/ft² and 64,500 gpd/ft², respectively.

In contrast, pumping tests in wells to the east of the eastern mound gave permeabilities of 10 gpd/ft² for the lower Ringold clays, 150 gpd/ft² for the middle Ringold conglomerate, and 1,400 gpd/ft² for the upper Ringold silts and sands.

SUMMARY AND CONCLUSIONS

Under natural conditions, the regional body of unconfined water at Hanford is perennially recharged by precipitation upon Rattlesnake Hills and Yakima Range. All natural ground-water movement is to the north and east toward the Columbia River with discharge into that stream, except at high river stage. However, the infiltration of large volumes of plant effluents has considerably altered the natural conditions. Thus the formation of two distinct ground-water mounds has increased and locally reversed the natural hydraulic gradients and consequently has accelerated the movement of much of the ground water.

A variety of hydrologic and geologic data have indicated three areas or channels of highly permeable glacio-fluvial deposits; these also are zones of rapidly moving ground water. Determination of the location, extent, and hydraulic characteristics of such zones permits the advantageous positioning of monitoring wells by which waste disposal criteria may be validated. From these data then, it is possible to predict with reasonable accuracy the behavior of low-level radioactive wastes discharged to the ground and to regulate the disposal procedures in order to provide conservatively safe operation for the plant, its environment, and its neighboring communities. It is most significant that at no time in the history of the plant has the underground movement of radioactive fission products resulted in detectable quantities reaching points of human access or beneficial use.

Obviously, waste disposal operations demand a multitude of approaches to assure safe operation; a most important one is the ability to determine empirically the behavior of at least some wastes in the zone of saturation.

*The coefficient of transmissibility is expressed as the rate of flow of water, at the prevailing water temperature, in gallons per day (gpd), through a vertical strip of the aquifer 1-foot wide extending the full saturated height of the aquifer under a hydraulic gradient of 100 per cent. The field coefficient of permeability introduces the idea of discharge of the aquifer per unit area instead of per unit width, and is commonly expressed in gallons per day per square foot.

Experience here, while based on specific local conditions, may prove useful for guidance in safe and economical waste disposal methods at other locations.

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SLEUTHING THE BEHAVIOR OF A RIVER^a

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(Proc. Paper 1847)

SYNOPSIS

Seven years ago the Ohio River Valley Water Sanitation Commission instituted a program for systematic surveillance and appraisal of quality conditions and flow variations. Purpose of this program, which includes the operation of a network of 43 monitor stations, is to provide a continuing record of vital information to aid in the diagnosis of stream conditions, to be alerted on pollution potentials and to provide the facts for the formulation of control measures. The author describes the genesis of the project, how the work is done in collaboration with volunteer monitors and the U. S. Geological Survey, the manner in which data is prepared for evaluation and the cost of the operation.

Sleuthing the behavior of a river suggests some obvious and even exciting possibilities for perfecting the art of pollution control practice. At least it should have appeal to those who feel that too often they have known too little too late about the varying moods of the streams with which they deal.

It was on this premise that the staff of the Ohio River Valley Water Sanitation Commission inaugurated a program of sleuthing river behavior—an operation that in more prosaic terms means systematic surveillance and appraisal of quality conditions and flow variations. Because of current interest in establishing a national network of river-quality monitor stations, your program committee suggested that it might be useful to outline experiences with the Ohio Valley project, which is now in its seventh year of development. In so doing the following aspects will be described: Genesis of the ORSANCO project; how the job is being done; interpretation of information; and what it costs.

Note: Discussion open until April 1, 1959. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 1847 is part of the copyrighted Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 84, No. SA 6, November, 1958.

- a. Presented at the ASCE Convention at Chicago, Ill., February, 1958.
1. Executive Director and Chf. Engr. Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio.

As a matter of orientation, it should be mentioned the Ohio River Valley Water Sanitation Commission is an interstate agency. It was established in 1948 by a compact among the states of Illinois, Indiana, Ohio, Pennsylvania, New York, Virginia, West Virginia and Kentucky. These eight states pledged a pooling of their resources and their police powers in a regional crusade for clean waters. To carry out this purpose a commission was created, consisting of three representatives from the Federal Government appointed by the President of the United States. The role of the commission is to promulgate interstate pollution-control regulations and to assert such powers as may be necessary for the enforcement of obligations outlined by the compact.

Genesis of the ORSANCO Monitor Project

The ORSANCO stream-surveillance project had its genesis in the fall of 1951. At that time the executive director requested Commission authorization to initiate a program for securing river-quality and flow information on a continuous and systematic basis.

It was pointed out that in dealing with a dynamic river system like the Ohio—which includes 1,000 miles of main-stem and 19 major tributaries—something better than sporadic stream surveys were required for diagnosis of river conditions and the formulation of control measures. Furthermore, since there are hundreds of industries and municipalities discharging wastes into the river system at various points, the question of checking compliance with control requirements foreshadowed the necessity for a monitor program. And finally, through routine observation of quality variations at selected points on the river it would be possible to institute a system for alerting downstream water users of abnormal conditions as well as fix responsibility for their origin.

From these considerations emerged the concept of establishing a network of monitor stations whose activities would be coordinated to produce a comprehensive array of facts about the river. How this ideal conception might be realized within the limitations of a small budget was something else.

Thus, armed with more enthusiasm than funds, the Commission invited the interest of eleven managers of public and private waterworks plants situated at various points along the Ohio River. These men had more than an academic concern with river-water quality, and they responded to an appeal to serve as volunteer monitors.

This resulted in the organization, on January 7, 1952, of the Water Users Committee of the Commission and the formal inauguration of the ORSANCO monitor project. Each member of the committee agreed to furnish a twice-weekly analysis of Ohio River water; this and much more, has been faithfully done for the past six years. Incidentally, operations of the committee, which meets every three months with the ORSANCO staff for an exchange of experiences has not exceeded the \$1,000 allotted annually in the Commission budget.

Two years later in 1954, the Commission budget permitted execution of the next step in the program. This was the establishment, under a contract arrangement with the U. S. Geological Survey, of six additional monitor stations. These stations are located near state lines and other strategic points where quality information was desired. The \$5,000 made available by

ORSANCO was matched with an equal sum by the U.S.G.S., which is a typical arrangement under the cooperative basic-data program so ably conducted by the Geological Survey for many years.

A year later, the U.S.G.S. contract was amplified to include analyses during low-flow months for certain trace constituents, notably those in the heavy-metals group. Three locations on the Ohio River were chosen for these observations.

Beginning in October, 1956, the contract with the U.S.G.S. was expanded further to secure quality data from twenty-one additional stations, mainly on tributaries to the Ohio River. Fifteen of these are cooperatively financed by the Commission and the remainder by Kentucky, Ohio and Pennsylvania.

Thus, the present ORSANCO monitor network includes stations at 43 locations. Fifteen are serviced by an enlarged Water Users Committee on a volunteer basis, and the remainder under contract with the U.S.G.S.

How the Work is Done

Operating the network and maintaining the records obviously calls for a nice coordination of activities. This was initially undertaken by Robert K. Horton, M. ASCE, assistant director of ORSANCO. For the past two years the project has been supervised by David A. Robertson, Jr., J.M. ASCE, staff sanitary engineer and hydrologist. Aid in the interpretation of data is furnished by Harold W. Streeter, M. ASCE, who serves as staff consultant.

Activities of the volunteer monitor stations are coordinated through the Water Users Committee. The members, each of whom operates one station, meet every three months with the staff and representatives of the U.S.G.S. This provides opportunity for discussion of analytical techniques, review of observations and the exchange of experiences. In addition, it offers a unique opportunity for the ORSANCO staff to become intimately acquainted with conditions at municipal and industrial water-treatment plants as revealed by practical experts in processing or river water. This is an important dividend in terms of providing the staff with essential background to aid in the evaluation of analytical data.

When abnormal situations occur on the river—as evidenced by a spill, detection of a slug of waste or a fish-kill—members of the committee alert ORSANCO headquarters by telephone. In turn, our headquarters keeps the monitor stations informed regarding unusual conditions revealed by incoming data. In this fashion a patrol system of great usefulness has been established. It serves two important purposes: (1) provides a ready means to alert all downstream water plants of potential difficulties so that steps can be taken to cope with a situation; and (2) facilitates the task of determining where the trouble originated so that steps can be taken by the appropriate state control agencies to prevent a recurrence.

There have been several occasions where the Water Users Committee monitor stations made it possible to quickly bracket a stretch of river and pin down responsibility for troublesome situations. One of these involved a thoughtless industrial plant manager who ordered the by-passing of a recovery unit in order to make some repairs, with the resultant discharge of several thousand pounds of phenolic wastes and the temporary ruination of a water supply. Prompt notification to downstream users of this slug of waste helped to minimize trouble at other places.

Another incident concerned a shift-foreman at an industrial plant who shut down his operations on a Friday night for the week-end but forgot to stop a pump that was filling storage tanks with oil. The tank overflowed into a creek leading to the Ohio River. When a boat club notified us that the river was a mess, we were able to bracket the discharge between two upstream monitor stations. This information relayed to the appropriate state agency made it possible for field inspectors to spot the location and halt the pumping, which had continued unobserved by the plant watchman.

This, then, is an accounting of the manner in which the volunteer monitor stations function. Now for some comments on the U. S. Geological Survey stations. Nine of these are located at navigation locks and dams where an arrangement has been made with the U. S. Corps of Engineers for collection of samples. At the remaining six stations samples are collected through a contract arrangement with a local resident.

Samples are picked up by a truck operating from the Columbus, Ohio laboratory of the Geological Survey, which makes its rounds on a semi-monthly schedule. At a few remote stations where the extension of this routine pick-up service would be costly, the samples are shipped by Railway Express.

In the Columbus laboratory a measurement of specific conductance is first made on each of the daily samples to provide a quick check on the day-by-day variation, if any, in quality. The daily samples are then made up into 10-day composites for analysis.

However, this routine applies only to samples used for mineral analysis. Samples for constituents that have a "fade-away" characteristic, such as cyanides and phenols, are individually collected and analyzed. The samples are chemically fixed at the time of collection and then sent by mail to the Columbus laboratory.

All of the U.S.G.S. analytical determinations, except those for certain Pennsylvania stations, are made under the direction of George Whetstone, district chemist of the Quality of Water Branch office at Columbus, Ohio, assisted by Paul G. Drake, project head, and T. R. Cummings, assistant project head. The Pennsylvania analyses are supplied by N. H. Beamer, U.S.G.S. district chemist at Philadelphia.

An important contribution to the ORSANCO monitoring program is the service rendered by the Surface Water Branch of the U.S.G.S. Provisional information on river flows is supplied in advance of publication from five Ohio River gaging stations. Floyd F. Schrader, M. ASCE, district engineer at Louisville, provides these records, assisted by W. L. Doll, A.M. ASCE, district engineer at Charleston, and Robert D. Schmicle, A.M. ASCE, engineer-in-charge, Pittsburgh area office. Similar advance flow data on certain tributaries in the State of Ohio is supplied by L. C. Crawford, M. ASCE, district engineer at Columbus.

Interpretation of the Information

Operation of the monitor network constitutes only one phase of the river-sleuthing project. Equally painstaking efforts are applied to recording and compiling the data.

But of paramount importance is conscientious review and appraisal of data promptly upon its arrival in the office. To do less than provide for

immediate scrutiny of the nature and meaning of information received and to relate this to prior observations, would be to deny a fundamental purpose of the surveillance program. Dedication to this task of prompt evaluation stems from the recognition that the quality-variation data are not to be regarded simply as historical events—here we are dealing with a form of vital intelligence.

Hardly a week goes by that does not furnish clues about something new that is happening in the river and how it relates to pollution-control practice. For example, our records reveal almost to the day when a certain industry placed into operation its new dephenolyzer unit; and we have an interesting picture of the times when difficulties were experienced in operating the unit at desired efficiencies. Again, we have the record of when and where an abnormal slug of chloride started down the river, as well as the time of arrival and magnitude of its effect at various points. Among other things, we are aware that there is a build-up of fluoride in a certain stretch of the river; and the records show that manganese and iron are occurring more frequently in unusual amounts.

These and other facts not only are alerting us to present and potential water quality problems, but provide a reliable basis for shaping judgment regarding appropriate means for coping with them. For example, if 95 per cent of a certain constituent in the river is traceable to natural sources, one would hardly display good engineering judgment by suggesting that control of 5 per cent originating from industrial wastes would have much effect on quality conditions.

The ORSANCO staff can assert with confidence that "sleuthing the behavior of a river" is no mere enthusiastic euphuism for an otherwise prosaic operation. One of the more prosaic elements, of course, is the collating of information. The manner in which the U.S.G.S. analytical and flow data are consolidated on a tabulation sheet for each monitor station is shown in Fig. 1. With slight variations, the same tabulation sheet was adapted for compilation of the Water Users Committee data (Fig. 2), and for the special analyses on heavy metals, cyanides and phenols (Fig. 2).

From this array of basic data as recorded for each station, each month and for each year, a pattern emerges and from this it becomes possible to compare, to probe and even to forecast conditions with some degree of assurance. A recent study related to chloride concentrations in the Ohio River is a case in point; the availability of four years of data made possible a most revealing diagnosis, one example of which is typified in Fig. 3. Similar comprehensive studies currently are being made with regard to other constituents preparatory to making recommendations for control measures based on the evidence of adequate facts.

Not the least important information derived from the monitor program is an accurate portrayal of the ranges of water quality. What the story is for the Ohio River as revealed from the first four years of record is shown in Fig. 4. With such a compilation the commissioners of ORSANCO—and anyone else who needs the facts—are provided with documented evidence on water-quality variations as revealed by minimum and maximum monthly averages as well as in terms of highest observed values.

OHIO RIVER...Newell, W. V. 1953

SAMPLING POINT - About 1,000 ft. upstream from Dam 8 (Sigsbee St.)

DRAINAGE AREA - 25,300 sq. mi.

RECORD PERIOD - Chemical analyses and water temperatures October 1904 to December 1956.

FLOW DATA - Flows are estimates for the U.S.G.S. gage at Indian Mills, Mo. They were computed from the discharge measurements at the gage and the relationship between discharge and flow data at the gage. The gage is a weir type and the relationship between discharge and flow data at the gage is as follows:

RELATIONSHIP - Sample collected daily for the U.S. Corps of Engineers. Analyses made by the U.S.G.S. at 15-day intervals. Large as noted, chemical analyses are in parts per million.

DATE	MEAN FLOW cfs	TEMP °F	SiO ₂	Al	Fe	Mn	Cu	Mg	NH ₄	K	NaCO ₃	NO ₃	Cl	F	PO ₄	SULFUR as SO ₄	MANGANESE as MnO ₂	ASBESTY as SiO ₂	SP. COND. at 17°C	pH	COLOR
1955																					
Jan. 1-10	112,000	47	6.5	0.5	0.25	0.25	18	5.3	5.5	1.4	7	43	4.4	5.1	2.2	113	68	61	187	6.2	1
Jan. 11-20	17,500	28	6.4	0.5	0.25	0.25	24	6.4	9.2	1.8	6	56	7.0	2.3	2.0	151	87	80	235	6.3	3
Jan. 21-31	17,500	28	6.4	0.5	0.25	0.25	24	6.4	9.2	1.8	6	56	7.0	2.3	2.0	151	87	80	235	6.3	3
Feb. 1-10	21,100	27	6.1	0.5	0.25	0.25	24	6.4	9.2	1.8	6	56	7.0	2.3	2.0	151	87	80	235	6.3	3
Feb. 11-20	17,500	27	6.1	0.5	0.25	0.25	24	6.4	9.2	1.8	6	56	7.0	2.3	2.0	151	87	80	235	6.3	3
Feb. 21-30	156,000	41	5.6	0.3	0.25	0.25	22	6.9	6.9	1.6	7	79	8.2	1.1	5.4	144	85	78	234	5.7	4
Mar. 1-10	133,000	48	5.7	0.3	0.25	0.25	22	6.9	6.9	1.6	7	79	8.2	1.1	5.4	144	85	78	234	5.7	4
Mar. 11-20	115,000	48	5.8	0.3	0.25	0.25	22	6.9	6.9	1.6	7	79	8.2	1.1	5.4	144	85	78	234	5.7	4
Mar. 21-31	89,000	44	5.9	0.3	0.25	0.25	22	6.9	6.9	1.6	7	79	8.2	1.1	5.4	144	85	78	234	5.7	4
Apr. 1-10	33,000	41	6.0	0.3	0.25	0.25	22	6.9	6.9	1.6	7	79	8.2	1.1	5.4	144	85	78	234	5.7	4
Apr. 11-20	33,000	41	6.0	0.3	0.25	0.25	22	6.9	6.9	1.6	7	79	8.2	1.1	5.4	144	85	78	234	5.7	4
Apr. 21-30	89,000	41	6.0	0.3	0.25	0.25	22	6.9	6.9	1.6	7	79	8.2	1.1	5.4	144	85	78	234	5.7	4
May 1-10	20,000	63	5.6	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
May 11-20	22,000	69	6.2	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
May 21-31	16,400	73	7.7	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
June 1-10	16,400	73	7.7	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
June 11-20	20,700	73	7.4	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
June 21-30	5,000	78	7.4	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
July 1-10	9,400	81	7.2	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
July 11-20	9,400	81	7.2	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
July 21-31	9,400	81	7.2	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Aug. 1-10	4,200	83	8.1	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Aug. 11-20	22,700	75	7.4	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Aug. 21-31	15,000	75	7.4	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Sept. 1-10	4,000	78	7.4	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Sept. 11-20	4,000	78	7.4	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Sept. 21-30	4,000	78	7.4	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Oct. 1-10	5,000	74	8.3	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Oct. 11-20	5,000	72	9.3	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Oct. 21-31	15,000	67	8.7	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Nov. 1-10	12,000	58	7.1	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Nov. 11-20	12,000	58	7.1	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Nov. 21-30	26,700	48	7.8	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Dec. 1-10	44,400	43	6.4	0.3	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Dec. 11-20	17,100	37	5.9	0.3	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Dec. 21-31	19,000	36	7.7	0.3	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3
Annual Average	26,900	65	7.3	0.2	0.25	0.25	28	7.3	11	2.0	9	98	8.0	0.2	2.2	173	94	88	272	5.2	3

WATER QUALITY MONITORING PROJECT - Ohio River Valley Water Sanitation Commission

Fig. 1. Standard tabulation sheet designed for monitor stations operated under contract by the U. S. Geological Survey. On it are consolidated both analytical and flow data for an entire year.

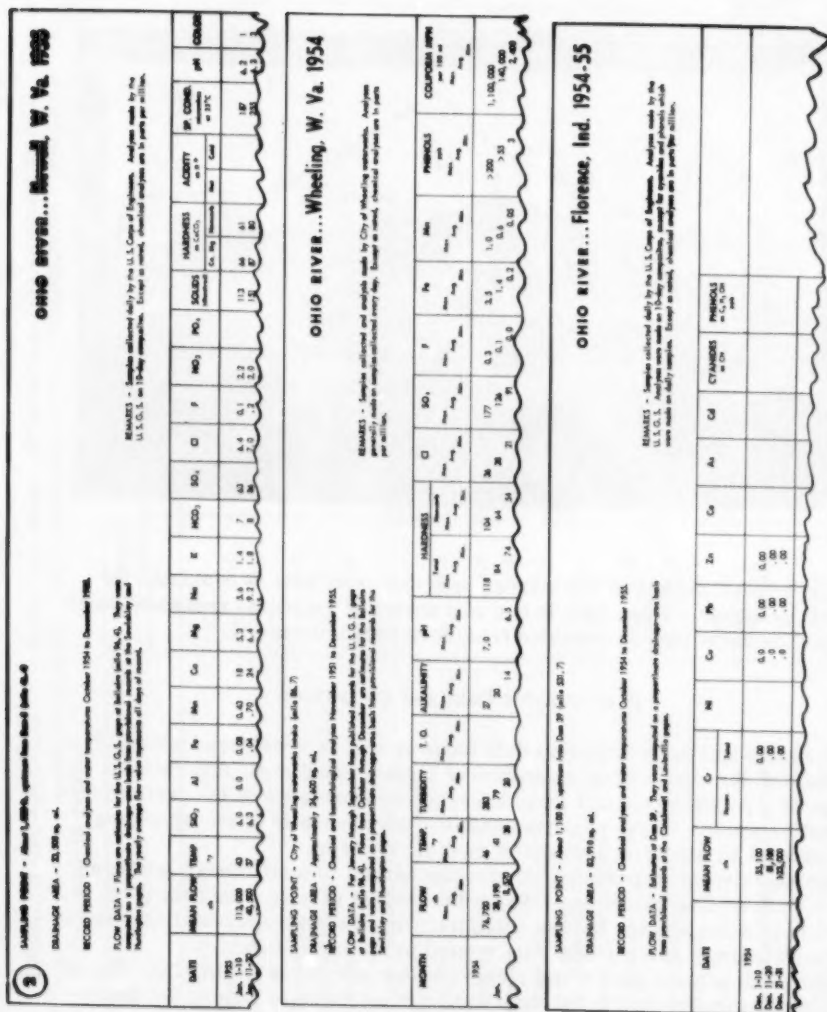


Fig. 2. With slight variations the standard tabulation sheet (top) has been modified to accommodate data from another type of monitor station (center) and for special analyses on heavy metals, cyanides and phenols (bottom).

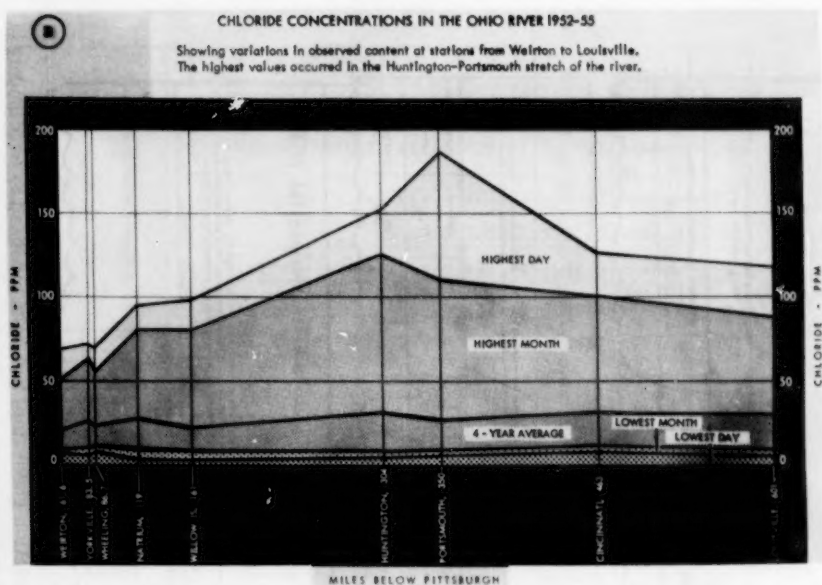


Fig. 3. An example of the manner in which basic data is evaluated for special purposes. This chart is one of a series of graphical representations of chloride variations as revealed from four years of record.

Hydrographic Data and Evaluation

Chemical and bacteriological data alone cannot be considered adequate, of course, for the engineering evaluation of stream conditions. And rational design of a pollution-control program requires knowledge of the availability of dilution water. These reasons commend the necessity of incorporating flow data as an essential element of monitor records.

Fortunately, information on stream discharges is meticulously gathered by the U. S. Geological Survey. From this wealth of long-time data it is possible to make studies for the establishment of the flow variability pattern of many streams, particularly with regard to minimum flows.

Such studies form part of the river-monitor project of ORSANCO. One of these deals with the statistical distribution of all flows of record for the development of so-called duration curves. With stream-flow pattern depicted in this form, it becomes possible to make accurate and rapid estimates of the availability of dilution water. A typical set of curves developed from daily flow records is shown in Fig. 5. This reveals the frequency of occurrence for flow of various magnitudes at each of four U.S.G.S. gaging stations on the Ohio River.

Duration curves have their limitations, however; they reveal only the pattern of availability of water based on all flows of record. In

4 RANGES IN QUALITY - in the Ohio River. Selected from data contained in this report. Results, except where noted, are in parts per million. Values with * indicate 10-day composite results.

Constituent	Range in terms of monthly-averages		Highest observed value
	Min.	Max.	
Alkalinity as CaCO_3	2	108	142
Aluminum (Al)	0.0	0.3	0.6*
Calcium (Ca)	20	58	70*
Chloride (Cl)	6.7	126	188
Color (units)	1	29	55*
Fluoride (F)	0.0	0.8	1.0
Hardness as CaCO_3 - Total	61	271	353
Hardness as CaCO_3 - Non-carb	37	244	342
Iron (Fe)	0.0	2.4	5.0
Magnesium (Mg)	6.0	17	19*
Manganese (Mn)	0.0	1.2	2.0
Nitrate (N)	1.1	7.5	9.6*
Odor (threshold number)	1	71	200
Phenols as $\text{C}_6\text{H}_5\text{OH}$ (ppb)	1	84	200
Potassium (K)	1.4	4.6	5.8*
Silica (SiO_2)	3.0	11	19*
Sodium (Na)	5.0	40	45*
Solids (dissolved)	137	390	440*
Specific conductance (in micromhos)	220	600	652*
Sulfate (SO_4)	37	362*	451
Turbidity (units)	2	576	1500

Fig. 4. A summary sheet for quick appraisal of the ranges of observed water quality from four years of record.

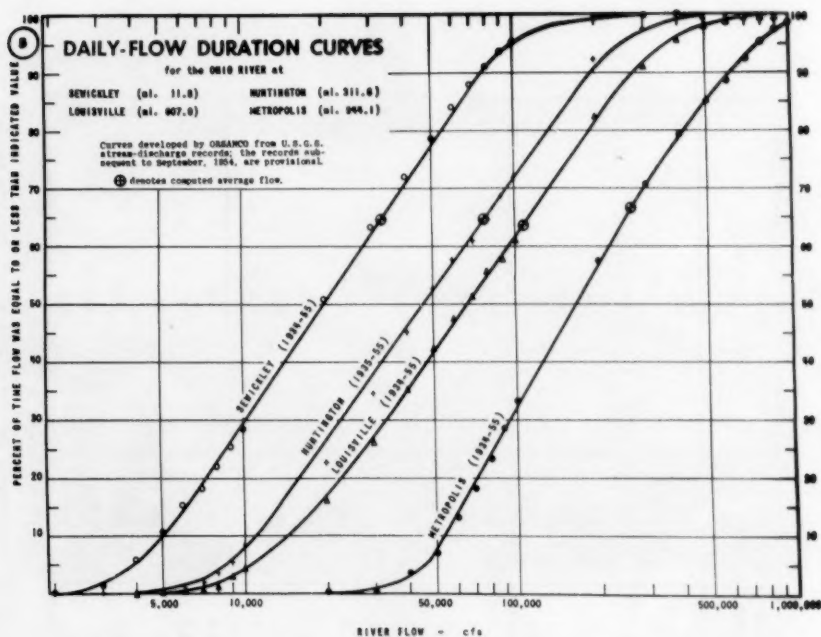


Fig. 5. A set of flow-duration curves prepared from stream discharge records of the U. S. Geological Survey. They show frequency of occurrence of flow of various magnitudes at each of four gaging stations.

pollution-control practice a primary concern is with minimum stream flow and its probability of occurrence. Hence the ORSANCO hydrographic studies are designed to include an analyses of drought-flow probabilities—specifically, a determination of the minimum daily, weekly, two-week and monthly flows.

Results from a typical drought-flow analysis tabulation are shown in Fig. 6. The first table shows the flows computed for various drought-severity classifications. The second lists the observed minimum daily flow for each year and with it the computed value for various time intervals. The third table shows the flows augmented by the appropriate increment of flow resulting from discharge of water from upstream, multiple-purpose reservoirs operated under direction of the U. S. Corps of Engineers.

The drought flow probabilities, which were developed by Mr. Robertson, are based on the statistical theory of extreme values developed by E. J. Gumbel (see "Probability Interpretation of Observed Return Periods of Floods". *Trans Amer. Geophysical Union*, Part III, page 836, 1941).

In Fig. 7 is shown a schematic representation of minimum monthly flows in the Ohio River to be expected for both the 5 and 10-year drought frequency. Also shown on the chart are the names and mile-point locations of major tributaries to the Ohio River; this feature adds considerably to its reference value.

LOUISVILLE GAGE Drought-flow analysis tabulations

Table L-1 Drought streamflow experienced during winter-spring season. These values, expressed in cubic feet per second (cfs), were computed for the augmented flow of Louisville as shown in Table L-2.

Drought severity	Minimum Daily Avg. (cfs)	Minimum Weekly Avg. (cfs)	Minimum Monthly Avg. (cfs)
More probable drought	7,720	11,000	12,140
Once in 5 years	6,130	8,830	9,220
Once in 7 years	5,700	7,660	8,490
Once in 10 years	5,390	6,980	7,740
Once in 15 years	4,840	6,225	6,910
Once in 20 years	4,320	5,490	6,340

Table L-2 Minimum flows at Louisville 1934-55. These values were computed for various times (generally from daily and monthly discharge records published by the U. S. Geological Survey). Flows are expressed in cfs. * Indicates date flow previously occurred.

Year	Day	Week	Two Weeks	Calendar Month	Month when flow occurred
1934	4,000	8,870	10,000	14,300	July
1935	10,600	12,600	13,210	16,800	Oct.
1936	4,130	8,000	8,320	10,010	Sept.
1937	4,180	9,710	10,720	33,420	Sept.
1938	4,000	9,440	10,360	12,270	Oct.
1939	5,200	6,400	7,740	9,790	Sept.
1940	7,200	10,100	10,930	12,930	Oct.
1941	5,360	7,390	8,470	16,170	Oct.
1942	15,200	19,940	27,390	33,720	Sept.
1943	5,130	6,430	6,880	12,430	Oct.
1944	9,130	9,380	10,030	13,440	Aug.
1945	10,700	14,490	16,390	34,310	July
1946	5,300	7,910	8,970	11,000	Sept.
1947	9,730	12,400	14,430	16,050	Oct.
1948	5,780	11,460	13,340	17,450	Sept.
1949	11,000	15,070	17,390	18,930	Oct.
1950	18,000	24,070	29,710	37,000	Aug.
1951	6,000	10,860	11,440	12,330	Oct.
1952	4,000	7,030	8,070	9,240	Oct.
1953	4,200	6,000	6,800	7,200	Oct.
1954	8,600	10,300	11,440	20,400	Sept.
1955	7,130	9,210	9,360	11,740	Sept.

Table L-3 Augmented minimum flows at Louisville. These values represent the flows shown in Table L-2 plus the augmented flow resulting from operation of multiple-purpose reservoirs in the upper watershed of the Ohio River. Flows are expressed in cfs.

Year	Day	Week	Two Weeks	Calendar Month
1934	4,210	12,300	11,300	17,410
1935	12,210	14,210	14,620	19,210
1936	7,360	9,410	9,780	16,430
1937	5,260	11,120	12,130	34,530
1938	5,670	10,110	11,330	13,340
1939	6,270	7,470	8,810	9,660
1940	8,270	11,170	12,020	14,020
1941	6,430	8,460	9,540	17,340
1942	16,270	27,010	36,660	34,790
1943	6,200	7,200	7,790	13,350
1944	9,030	10,380	10,790	14,140
1945	11,400	13,190	17,000	33,010
1946	6,200	8,610	10,670	11,730
1947	10,430	12,100	13,500	16,730
1948	5,900	11,440	12,940	17,450
1949	11,200	15,770	17,390	19,130
1950	18,200	24,770	29,710	37,230
1951	6,200	11,060	11,840	12,350
1952	4,430	7,730	8,670	9,960
1953	4,230	6,000	6,800	7,200
1954	8,600	10,300	11,440	20,400
1955	7,130	9,210	9,360	11,740

Fig. 6. In pollution-control design practice a primary concern is with minimum stream flow and its probability of occurrence. These tabulations summarize the drought-flow analysis results.

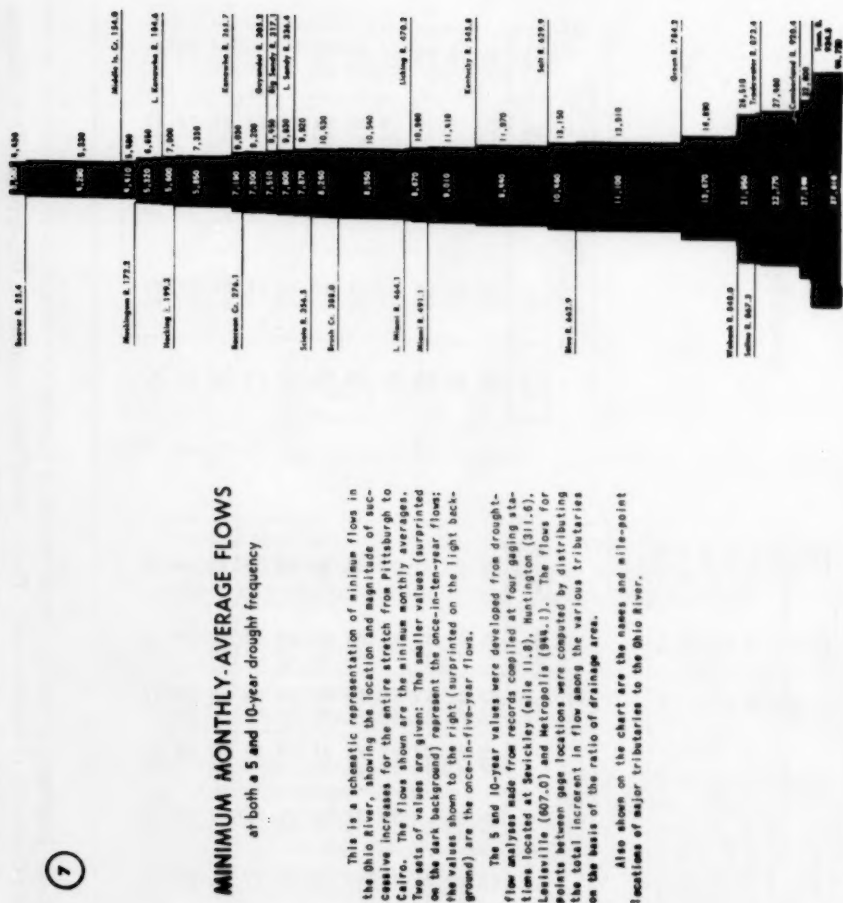


Fig. 7. Schematic representation, called the "Empire State" Building Chart, of minimum monthly flows to be expected at both the 5 and 10-year drought frequency at various points along the 1,000-mile Ohio River.

Incidentally, all of the chemical, bacteriological and flow data for the first four years of record have been published in book form. Copies of this 112-page report are made available free to all federal, state and local agencies engaged in water-resources activities and to any other tax-supported agencies in the Ohio Valley; a nominal charge of \$2.00 is made to others. Supplemental information is being compiled for publication on a yearly basis and the work-sheet records are always open for examination at the Commission headquarters.

What Does it Cost?

Collection and analyses of stream samples is generally conceded to be one of the more costly elements of a water-pollution control program. It is not unusual for single stream surveys of only a few months duration and of limited scope to range in cost from \$10,000 to more than \$75,000. What then, is the cost of conducting a monitor program to provide a continuous and systematic record of stream-quality?

Cost information from the ORSANCO monitor program may be helpful in making such an evaluation. A summary covering the first four years of record is shown in the accompanying tabulation. Since the number of stations, as well as the number of months they were in operation, has varied from year to year, the comparisons are made on a "station-month" basis. (Fig. 8)

<div>8</div> SUMMARY OF MONITOR-STATION COSTS					
	1952 (116 sta.-mos.)	1953 (141 sta.-mos.)	1954 (164 sta.-mos.)	1955 (240 sta.-mos.)	TOTAL
Direct costs to ORSANCO (including staff time)	\$ 3,000	\$ 3,000	\$ 4,300	\$ 10,000	\$ 20,300
Estimated value of volunteer and contract services	20,000	25,000	28,000	38,000	111,000
	\$ 23,000	\$ 28,000	\$ 32,300	\$ 48,000	\$ 131,300
Average cost per station per month	\$ 200	\$ 200	\$ 200	\$ 200	

Fig. 8. Summary of monitor-station costs. The estimated value of services rendered through volunteer and cooperative-contract arrangements is about 6 1/2 times the direct costs.

There are several things about this tabulation that deserve a word of explanation. It will be recalled that in developing this program ORSANCO enlisted the volunteer efforts of waterworks managers for securing data; the value placed on this effort is based on the estimated cost of equivalent services from a private laboratory. The U.S.G.S. participation in the program is on a matching basis—thus, for every dollar of work contracted by ORSANCO another dollar's worth of service is added by the Geological Survey.

Depending on the number and type of analyses made, the yearly cost of operating a monitor station can vary from \$1,000 (the lowest value placed on data supplied from a Water Users Committee station) to \$3,700 (the highest value placed on data from a U.S.G.S. station).

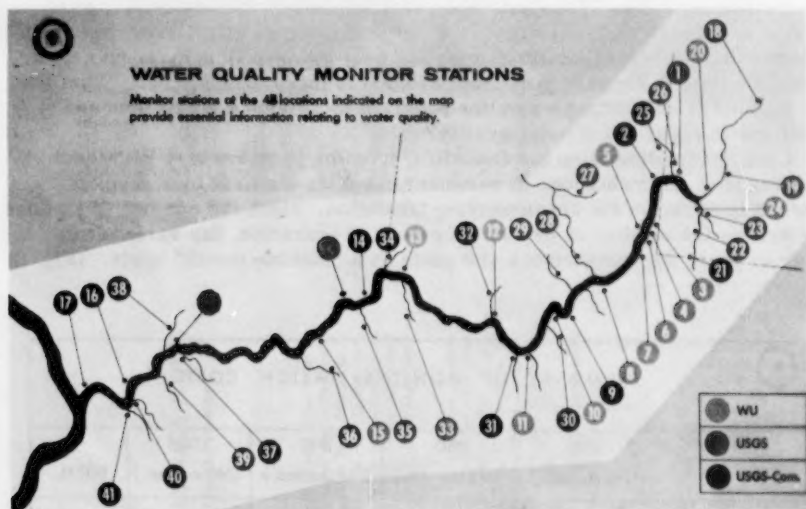


Fig. 9. The ORSANCO network of monitor stations. The WU stations are volunteer Water Users Committee locations. The others are operated by the U. S. Geological Survey, some on the basis of a cooperative contract arrangement.

The analyses made at the lowest-cost station include: turbidity, threshold odor, alkalinity, pH, and hardness.

Analyses at the highest-cost station include silicon, iron, manganese, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, fluoride, nitrate, phosphate, dissolved solids, hardness, specific conductance, pH, color, chromium, nickel, copper, lead, zinc, cobalt, arsenic, cadmium, phenols, cyanides, aluminum and acidity.

The value placed on collection and analysis for each sample varies from \$10 for five constituents up to \$120 for thirty constituents.

These estimates represent what it would have cost ORSANCO if it had not enlisted the voluntary services of waterworks managers or engaged in a cooperative program with the Geological Survey. The actual cost to ORSANCO for the four years of work was \$20,000. But the value of the data obtained is estimated to be \$131,000. Thus, for every dollar spent by ORSANCO the value received in data is something better than \$6 1/2.

Subsidiary and Future Monitoring

Among activities related to the diagnosis of stream-quality conditions are those concerned with radioactivity, detergent concentrations, algal growths and organic compounds associated with taste and odor problems.

With regard to monitoring radioactivity, such work has been conducted for several years in the Ohio Valley by the Atomic Energy Commission. In 1956 at the request of ORSANCO the Public Health Service, through its Taft Sanitary Engineering Center, secured "background" radiation counts in the Ohio River and at the mouth of certain tributaries. More recently, routine monitor procedures have been established by several of the states signatory to the Ohio Valley Compact, among them Ohio, Indiana, Illinois and Kentucky.

The commissioners of ORSANCO recently authorized a contract with the biology department of the University of Louisville to monitor radioactivity of the muds, biota and fishes in the Ohio River. This work is designed to supplement water quality information being collected by the Atomic Energy Commission and the states from a network of stations shown in Fig. 10.

For several years ORSANCO has been privileged to have the cooperation of the Procter and Gamble Company in Cincinnati on questions relating to detergents and river water quality. The company maintains a monitor station in the Ohio River, performs special analyses on samples from various places that are submitted from time to time by ORSANCO, and has a representative on the Water Users Committee of the Commission.

Events of last year during which there was a prolific growth of algae in the Ohio River has directed staff efforts toward routine assembly of data relating to this phenomena. Present plans include collection of information at certain existing monitor stations on the number and kinds of algae and probably ultra-violet light intensity. Phosphate and nitrate determinations already form part of the established program.

Another additional monitor operation that has been started on a modest scale concerns the extraction of organic compounds using the carbon-filter technique. This work, which is related to a detailed investigation of taste and odor problems, has been contracted to The Kettering Laboratory in Cincinnati.

One question that might occur is why dissolved-oxygen is not routinely monitored. The answer is that sufficient tests have shown that oxygen deficit has not yet become a problem in the Ohio River. Therefore, the expense of continuous monitoring of oxygen at this time was not believed to be justified. At one point in the river that might be considered critical, oxygen measurements are being made several times a week by the City of Cincinnati and these results are available to ORSANCO. At other points in the river oxygen measurements are made by the field crews engaged on the ORSANCO-sponsored investigation of aquatic-life resources. Meantime, we have been testing a new and relatively inexpensive instrument that offers promise as a means for simple, automatic monitoring of oxygen.

Looking toward the future and the possibility of securing more intimate surveillance of river-quality variations, we have for some years been entertaining ideas on what we are pleased to call a "robot monitor station" project. Using a portion of the Federal grant under Public Law 660, activities related to this project have been accelerated.

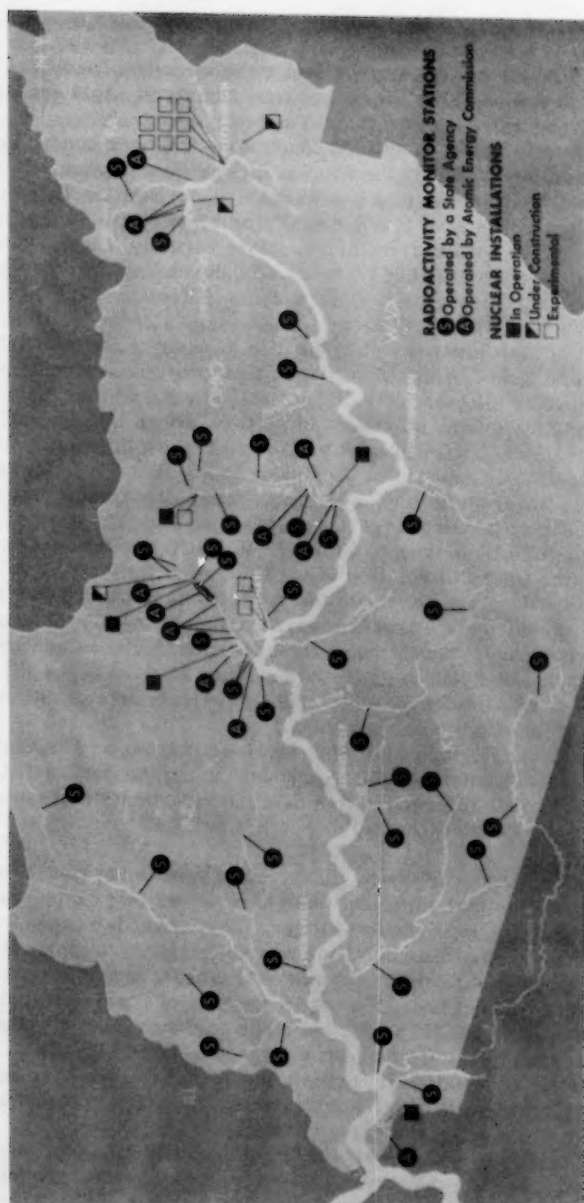


Fig. 10. Network of radioactivity monitor stations in the Ohio Valley. Those marked S are operated by a state agency and those marked A are operated by the Atomic Energy Commission.

The goal, broadly stated, is to investigate the engineering and economic feasibility of adapting analytical instruments for the continuous recording and automatic transmission of river-quality conditions and the development of a self-operating monitor station for this purpose.

Initial efforts have been directed toward determining the availability and applicability of analytical recording equipment. Some 50 instrument companies were contacted to learn what they might have to offer and their possible interest in working with the Commission on development of equipment not now available. Relatively little was found to be available in the form of easily adaptable equipment; and only a few companies are in a position to consider developmental work at this time. But several promising possibilities have been uncovered.

However, we have no illusions that robot-monitor stations will supplant the skilled and conscientious services of the ORSANCO Water Users Committee, the Geological Survey and the Corps of Engineers. It is through these agencies and the men that represent them that the Ohio River Valley Water Sanitation Commission must place primary reliance in sleuthing the behavior of its rivers.

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FORESTS AND WATER YIELD

Nedavia Bethlahmy¹
(Proc. Paper 1848)

INTRODUCTION

Over half a century ago (1897) the Federal Government passed a law that provided for the permanent administration of forest reserves carved out of the rapidly diminishing public domain lands. These forest reserves (now called national forests) were established in part to secure "favorable conditions of water flows." This law was not passed on the basis of facts established by experiments. But, over a long period of time keen observers of nature had developed a concept that forests have a regulatory function upon streamflow. Thus, with only opinions to guide them, our early legislators passed a law which was far-reaching in its effects.

Controlled experiments have now verified earlier concepts that streamflow is regulated by forests. And the knowledge gained from numerous experiments conducted both in this country and abroad has led to a new science of watershed management; a science that will gain in stature as more knowledge is accumulated.

Forests and the Hydrologic Cycle

The facts of the hydrologic cycle are generally known. Evaporated water from the ocean is blown inland, falls to the earth, and returns to its original source. Even ancient people knew part of the story. Ecclesiastes (1:7) reads: "All the rivers run into the sea; yet the sea is not full; unto the place from whence the rivers come, thither they return again." But only in recent times has the major role that forests play in this cycle been understood. Trees of the forest intercept both rain and snow; break the fall of the raindrops and let them drop onto a thick, luxurious carpet; and allow snow to accumulate in a shady environment. Tree roots permeate the soil and form a labyrinthine

Note: Discussion open until April 1, 1958. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 1848 is part of the copyrighted Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 84, No. SA 6, November, 1958.

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receptacle for infiltrating water, while root-hairs take their toll of the moving waters and send them back again into the air. Thus, is present the atmosphere with its water content of variable form, the lithosphere with its slowly moving groundwater, and connecting these two environments is the forest biosphere—a link of utmost importance to the engineer.

The atmosphere and lithosphere are beyond human control. The rain-making activities of the next generation of meteorologists may prove part of this statement wrong. But at present, the forest biosphere is the only element in the hydrologic cycle that is subject to the control of man and that can be manipulated for his benefit. For this reason, the engineer must keep informed of the watershed research activities of foresters and collaborate with them for the benefit of the public.

Forests, Surface Runoff, and Infiltration

A bare soil receives all of the rain and snow that fall on it. But that is not necessarily good. The engineer wants plentiful water, not a dearth nor an over-supply; but it must also be of good quality. Water from a bare soil is generally not good water. A falling raindrop has a great amount of kinetic energy. When a raindrop strikes a bare soil it exerts a three-dimensional effect: it moves soil particles both laterally and vertically. Large soil particles are dislodged, and fine particles are splashed into the air (Ellison, 1944; Osborn, 1954). The structure of the upper soil mantle is altered and the multitude of pores that provided natural passageways for infiltrating water are clogged. As a result, rain cannot enter the soil; it flows over the surface, gains momentum, increases in eroding ability, and quickly enters a stream with a full load of silt.

Forests modify these evil effects of a bare soil. Tree canopies catch rain drops and causes a mass distribution; part of the rain falls in stages from leaf to leaf until it finally reaches the ground, and another part flows down the stem and the trunk until it reaches the soil bereft of its striking power. Moreover, the forest floor is totally unlike a bare soil. Litter and humus cover the mineral particles and form a protecting element; organic colloids bind the mineral constituents into aggregates of soil particles that are not easily broken; and millions of roots form intricate passages for the downward movement of water into the groundwater reservoir. In contrast to a bare soil, water does not flow over the land; it seeps through the soil into the groundwater and eventually appears as streamflow. Water that enters a stream is clear, and fit for human consumption and industrial use.

In northern climates, forests affect infiltration in another way. Here the bare soil freezes during the winter into an impermeable mass. The so-called concrete frost (Post and Dreibelbis, 1942) prevents water from entering the soil and brings about rapid surface runoff. On the other hand, large areas of concrete frost do not form in forests, although sporadic patches may be found in adverse sites (Trimble et al, 1958).

The problem of an impervious soil mass, whether resulting from erosion, soil freezing, or a land-use activity, is but one aspect of the large subject that can be called the soil reservoir. Water supply engineers store water behind dams in reservoirs; but in a larger sense, the entire soil mass of a watershed is a huge reservoir. The flow of water in this reservoir cannot be controlled daily. But the characteristics of this reservoir can certainly be changed for

better or worse through man's activities, including logging, fire, grazing, road building, and a host of other activities that normally occur in forested areas. And once these characteristics are impaired, they can be restored to their former condition only after many years of great effort (TVA, 1955).

Watershed Management

Discussion, up to now, has concerned some of the basic elements that characterize the relation between the forest environment and water. Assembling these elements into a unified concept, the result is the starting point of the science of watershed management. Objectives of watershed management are maximum yields of usable water coupled with stability of the soil. These objectives are achieved by manipulating the vegetation and applying sound engineering practices. Basic principles of watershed management have been ascertained from controlled experiments conducted over the past 30 years, but much is still to be learned.

What tangible results can be expected from managing a forest for its water-yielding capabilities? Can the amount of water emanating from forested areas be significantly increased? Results of a few experiments indicate that waterflow can be increased by (1) cutting a forest, (2) thinning a forest, (3) cutting a forest understory, (4) cutting riparian vegetation, and (5) cutting a forest in a special way to induce snow accumulation. The fact must also be stressed that logging must be accomplished in a way that will not destroy the forest soil characteristics.

Thirty years ago a watershed experiment was conducted in Colorado (Bates and Henry, 1928). Later, a similar experiment was conducted in North Carolina (Hoover, 1944). Both experiments showed that streamflow increased significantly when the forest was cut. The increases varied from 16 percent to more than 60 percent, depending in part on the conditions that followed logging. In these experiments logging was not done in the normal fashion; logging roads were not constructed, and heavy machines did not damage the soil.

Obviously trees use water; and if all the trees are removed, more water is available for streamflow. But what happens if only a part of the forest stand is cut? In Japan (Katsumi, 1956) 45 percent of a stand was removed selectively and streamflow increased by 1.2 inches in the summer and 3.4 inches in the winter.

In some forests the undergrowth is very dense. An experiment in a hardwood forest in North Carolina (Johnson and Kovner, 1956) showed that annual streamflow increased 4 percent when its dense understory of laurel and rhododendron was cut.

One other type of vegetation is important to watershed managers. Trees and shrubs that grow along stream courses consume large quantities of water. If these plants are removed, will streamflow be affected? An experiment in the humid east (Dunford and Fletcher, 1947) showed that the removal of riparian plants did increase streamflow. All the plants growing within 15 feet in elevation above a stream channel were removed. As a result, the stream no longer had a diurnal fluctuation, and during a ten-day period its flow increased by 12 percent.

In the west, a large part of the streamflow originates in the melting snows of the highlands. Snow accumulates during the winter months and melts in the

spring and early summer, causing streams to rise. However, streamflow diminished rapidly during the summer. Is it possible to prolong streamflow into later in the season? The answer may be "yes." Research in Colorado (Wilm and Dunford, 1948; Goodell, 1952) has shown that cutting in a lodge-pole pine forest increased the amount of snow accumulated during winter, thereby increasing the quantity of water available for streamflow. Further research is now under way to test this thesis on measured watersheds.

The experiments cited show that cutting forest stands increases streamflow. However, these cuttings were not made in the normal way. Commercial logging is accomplished with big equipment: bulldozers, road graders, and trucks. Bulldozers can destroy many of the qualities of forest soil that are essential to water regulation. Investigators (Steinbrenner and Gessel, 1955) have shown that tractors reduced permeability rates by 92 percent, and that a large part of the siltation from logged areas comes from poorly constructed roads (Lieberman and Hoover, 1948). Other investigators have shown that good planning can drastically reduce the mileage of logging roads, and that a watershed manager must select the proper logging method to safeguard the forest soil.

Interest in watershed management is gaining momentum. As proof let a specific case be cited. For over half a century the City of Portland has obtained its water from a stream originating in the Mt. Hood National Forest. Since its establishment, all grazing and logging have been excluded from the Bull Run District of this forest. Portland is now interested in finding out whether this area can be managed for both water and timber resources, thereby deriving increased water yields and also timber crops. The City of Portland has such a great interest in this problem that it is cooperating with the U.S. Forest Service in conducting watershed management research in the area. The cost is high, but Portland has much to gain, and to the author's knowledge is the first city with the foresight to attack its water supply problem through basic research in watershed management.

To summarize: The forest environment, which includes a well-developed soil, is essential to safeguard water supplies. Forests use large quantities of water, but can be manipulated so as to reduce this consumption. Thus, in the practice of watershed management there is a dual objective: To manage forests for their water resources, without impairing the forest soil characteristics. Research has shown that these objectives can be attained.

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ANAEROBIC CONTACT PROCESS FOR TREATMENT OF
SUBURBAN SEWAGE

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(Proc. Paper 1849)

ABSTRACT

Pilot plant studies are described on an anaerobic contact process incorporating simplicity of design and absence of moving parts for treatment of domestic sewage. The process which produces an effluent low in BOD and suspended solids is being developed for small groups of houses.

A need for workable means of suburban sewage treatment has been growing throughout the United States. It is most acute in isolated suburbs with poor soil absorption characteristics.

A scheme of sewage disposal that has great practical merit is the subdivision sewer system connected to a small treatment plant. The planned location of these small treatment plants in a drainage basin makes integration into a large sanitary district possible. Trunk sewers can be constructed later connecting the subdivision sewer system, eliminating the smaller interim plants in favor of one large treatment plant. The cost of suburban sewer systems and small plants installed during the construction of a housing project has been shown to be often less than individual disposal units.⁽¹⁾ This suburban system will increase the value of the property and decrease the health hazards of waste disposal in areas unfit for individual units.

Note: Discussion open until April 1, 1959. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 1849 is part of the copyrighted Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 84, No. SA 6, November, 1958.

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The acceptability of a scheme of suburban sewers and plant lies in the suitability of the small sewage treatment plant selected. A disposal plant must be judged on the quality of effluent it produces.⁽²⁾ However, from the practical viewpoint, the suitability of a small disposal plant depends upon the economics of producing an effluent quality that will protect the health and property of the people in the area.

The treatment facilities should be low in original cost, and operational cost must be kept small by designing the plant to require little maintenance. The first cost of this system of sewers and small plants must be justifiable to the builder. The increase in property value, the absence of land requirement for individual disposal fields, the ability to obtain Federal loan insurance, and the initial cost of this system must be economically favorable over the individual disposal units. Maintenance costs must be held to the normal monthly 1 to 4 dollars per connection sewer charge. In essence, this means weekly or monthly maintenance.

Previous Laboratory Studies

In a laboratory bench-scale study, a long detention in an anaerobic sludge contact tank followed by an upflow rock column gave promising performance.⁽³⁾ This unit removed 67 per cent of the BOD (Biochemical Oxygen Demand) under cold weather conditions and 81 per cent under warm weather conditions, and gave high suspended solids removal, above 90 per cent under both conditions. Since the process required no moving equipment and little maintenance, it promised exceptionally low original and maintenance cost.

General Description of the Anaerobic Contact Process Pilot Plant

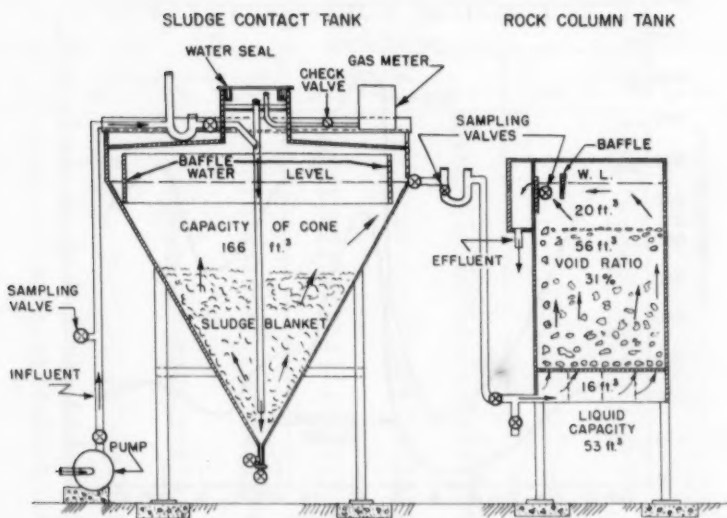
Following the encouraging laboratory investigation, an anaerobic contact process pilot plant was initiated at Loveland, Ohio, on the grounds of the village sewage treatment plant. This study has now been in operation for over a year, and the effects of a yearly temperature cycle have been observed.

The pilot plant receives domestic sewage from the influent line of the existing primary clarifier. Raw sewage is first brought into contact with the sludge zone in the bottom of the first tank and flows upward to an outlet at the top of the tank. The effluent from this unit then flows upward through a submerged rock column and discharges back into the village treatment plant. Both units used in the process are operated under anaerobic conditions.

Fig. 1 shows a cutaway of the pilot plant. The primary tank is conical in shape, and has an 18-hour detention. The secondary tank is a 4' x 4' x 7' column, and has a 6-hour detention. The flow is 1.15 gal/min; its direction is shown by the arrows on the figure. Samples were taken in such a manner that each of the two units could be evaluated as a separate process. Analysis of accumulated data has led the authors to discuss these units separately.

The Sludge Contact Unit

The primary unit was designed to incorporate the anaerobic sludge contact principle which has been successfully used in treating industrial waste.⁽⁴⁾ Raw sewage is introduced at the bottom of the tank and immediately comes into contact with the blanket of digesting sludge. The incoming sewage flowing upward through the sludge zone mixes with the digesting sludge, and a large



CROSS SECTION OF LOVELAND PILOT PLANT

FIGURE 1

percentage of the fresh solids are removed. The clear liquid volume above the sludge zone provides time for resettling of the fine sludge particles carried from the blanket by sudden increases in the flow.

The conical tank, as seen in Fig. 1, has a capacity of 1240 gallons and the slope of the side is 60° with the horizon. The outlet is protected by a scum baffle. Automatic sampling valves on both the influent and effluent lines released samples every half hour which were composited in appropriate containers. Precautions were taken to prevent gas leaks and the entrance of atmospheric air. All gases generated in the tank must either escape from the tank through the wet test meter or be dissolved in the liquid effluent.

Suspended Solids, COD, and BOD Removals

The sewage entering the pilot plant showed suspended solids and BOD strengths typical of a domestic source. Fig. 2 shows the daily fluctuation of COD (Chemical Oxygen Demand) and suspended solids strength. These curves represent the average of data obtained from hourly samples taken over a 24-hour period on three separate days. The standard 5-day BOD test and the COD test using AgSO_4 catalyst were made on daily composites for the first 7 weeks. The relationship between BOD and COD for Loveland sewage was found to be $\text{BOD}(\text{ppm}) = 0.38 \text{ COD}(\text{ppm}) - 20$. For the balance of the year the convenient COD test was used on daily composites, and the BOD was run on one sample a week as a check on the BOD-COD relationship. These checks did not reveal any significant change.

In Table 1, average suspended solids, COD, and sulfides are given for the sludge contact tank. The table has been divided into a break-in period (weeks 0-15), a cold-weather period (weeks 16-36), and a warm-weather period

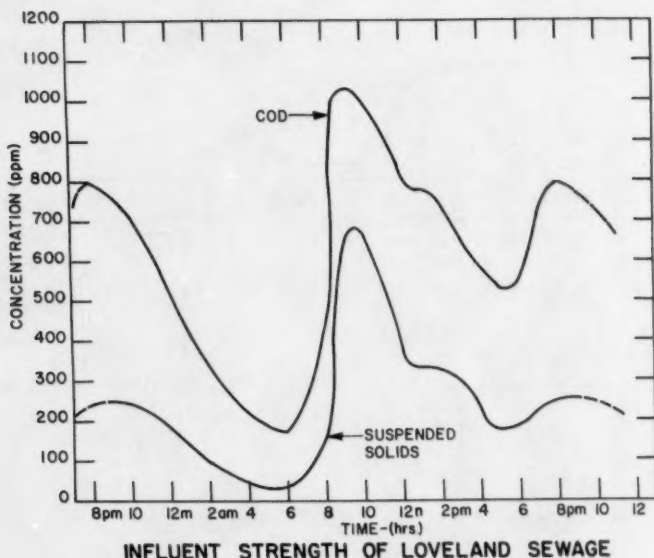


FIGURE 2

(weeks 37-52). Average removal over the year was 83 per cent suspended solids and 62 per cent COD. The primary effluent was inoffensive in odor with an average of 2.8 ppm of sulfide. Removals of both COD and suspended solids varied with temperature. During the warm seasons of the year, removals were greater than those obtained during winter operations. From November to March, when the mean air temperature was below 3.5°C , the primary unit removal averaged 54 per cent of COD and 74 per cent of suspended solids. From April to July, in which the mean air temperature was 19.7°C , average removals of 77 per cent COD and 88 per cent suspended solids were obtained.

Fig. 3 is a tabulation of the weekly averages of the determination made on daily samples from the pilot plant. Figs. 4 and 5 show graphically the operational data tabulated in Fig. 3. These curves present the magnitudes of COD and the suspended solids of the effluents, and give the magnitude and variations of removals with time in the sludge contact tank. The figures show the variation of efficiency with temperature. Both suspended solids and COD removals increased after the temperature rose above 10°C .

Gas Production

All gas produced in the tank must either leave through the gas meter or be dissolved in the effluent. A daily record of gas passing through the meter was kept and on several occasions analyses were made of the effluent. During the year, only 600 cu. ft. passed through the meter. Gas analysis demonstrated little or no methane (CH_4) and negligible carbon dioxide (CO_2). On two occasions effluent samples were stripped of dissolved gases by scrubbing with

TABULATION OF DATA

Weekly Averages										
Weeks	Suspended Solids (ppm)			COD (ppm)			Sulfide (ppm)			Air Temp (°C)
	Inf.	Pri Eff	Sec Eff	Inf.	Pri Eff	Sec Eff	Inf.	Pri Eff	Sec Eff	
1	260	53	38	564	309	287				
2	332	59	40	683	336	298				
3	328	37	22	725	317	288				25.6
4	377	46	22	854	364	301				27.8
5	275	63	28	619	307	265				23.5
6	327	112	31	655	413	316	7.6	15.0		27.4
7	298	71	16	671	267	244	6.5	16.3		23.3
8	332	44	25	678	286	276	7.0	16.5		25.6
9	278	41	23	672	272	252	6.0	14.6		18.1
10	332	120	56	747	372	318	7.5	16.2		19.0
11	303	98	49	685	335	289	6.0	13.0		19.8
12	256	62	30	662	339	283	1.2	4.3	10.0	15.9
13	480	58	36	717	321	286	0.1	3.0	13.0	21.4
14	392	50	23	727	334	295	1.0	4.4	15.0	17.1
15	424	75	42	801	365	309	2.3	9.6	15.4	18.5
16	253	59	29	—	363	315	3.0	5.2	14.0	8.5
17	313	50	43	—	403	343	5.5	5.0	15.5	9.6
18	249	83	31	—	405	304	2.2	5.0	12.8	8.4
19	229	70	42	—	345	276	2.0	4.0	13.5	1.8
20	416	81	50	1109	347	289	4.0	4.4	14.4	13.4
21	168	95	43	618	329	233	0.8	3.2	12.2	3.7
22	242	71	32	829	315	240	0.5	2.7	13.2	7.1
23	—	—	—	—	—	—	—	—	—	4.9
24	286	54	26	598	348	255	0.0	1.6	9.0	-4.6
25	226	85	50	698	367	258	0.0	0.8	6.2	-1.9
26	199	50	25	584	260	229	0.0	0.0	4.3	-9.7
27	—	—	—	—	—	—	0.0	0.0	5.2	0.5
28	298	75	60	537	241	208	0.0	0.1	6.4	-0.4
29	208	73	39	495	212	166	0.0	0.2	7.0	2.6
30	248	54	30	398	162	130	0.0	0.0	4.8	-0.3

CO₂. Analysis of the resulting mixture of CO₂ and the gases stripped from the solution failed to demonstrate any measurable CH₄.

TABLE 1 - SLUDGE CONTACT TANK

Months	Weeks	Suspended Solids			COD			Sulfides	
		Inf	Eff	% Removal	Inf	Eff	% Removal	Inf	Eff
July-Oct.	0-15	333	66	80	697	327	53	1.5	6.2
Nov-March	16-36	286	73	74	634	293	54	0.9	1.8
Apr-July	37-52	671	77	88	743	171	77	0.1	1.8
July-July	0-52	429	72	83	695	263	62	0.6	2.8

Sludge and Scum Accumulation

There was an absence of scum formation in the sludge contact tank as is present in other anaerobic systems, such as the Imhoff tank and septic tank. The presence of spring and summer temperatures did not produce an upset as is common in other anaerobic systems, caused by the violent spring gas production with resulting solids dispersion through the tank liquid.

The sludge in the contact tank, because of its importance in the method of treatment, has been studied in detail. Because the laboratory study was begun with the use of seed sludge, it was decided to determine if the unit would

Weeks	Suspended Solids (ppm)			COD (ppm)			Sulfide (ppm)			Air Temp (°C)
	Inf.	Pri Eff	Sec Eff	Inf.	Pri Eff	Sec Eff	Inf.	Pri Eff	Sec Eff	
31	348	79	55	675	251	162	0.0	0.4	4.7	1.5
32	257	76	33	505	224	141	0.0	0.5	4.7	2.5
33	248	72	32	449	185	127	0.0	0.4	6.5	1.7
34	—	94	47	—	244	181	0.0	1.0	6.2	11.7
35	—	—	—	—	—	—	0.0	0.4	6.7	6.8
36	671	98	44	754	278	209	0.1	0.7	6.2	5.7
37	764	159	33	567	193	134	0.0	0.5	6.2	10.3
38	605	45	22	384	115	91	0.0	0.0	3.3	5.7
39	498	58	39	588	171	145	0.0	0.1	4.5	11.7
40	932	52	35	727	153	175	0.0	0.1	7.9	22.2
41	532	68	36	775	172	185	0.0	1.0	10.6	17.3
42	436	93	45	345	232	251	0.0	2.0	11.3	20.1
43	1083	84	43	1194	241	279	0.1	2.6	10.2	23.7
44	1004	54	40	704	134	187	0.1	1.3	7.1	20.3
45	576	52	44	611	131	174	0.0	1.7	8.1	19.0
46	546	63	49	609	163	207	0.0	3.0	11.8	25.4
47	585	90	53	833	183	262	0.1	3.2	12.2	25.8
48	576	92	86	904	244	332	0.1	2.4	10.6	27.9
49	492	100	73	726	158	243	0.1	2.7	11.8	23.7
50	812	63	56	745	130	191	0.1	1.9	12.3	24.2
51	460	78	74	749	157	230	0.2	2.9	11.8	25.8
52	835	79	85	929	163	194	0.4	3.9	11.6	26.7

TABULATION OF OPERATIONAL DATA

FIGURE 3

function initially without the use of seed sludge. The sludge contact unit started with a 45 per cent removal of COD and an 80 per cent removal of suspended solids. During the first 9 weeks of operation a sludge accumulation of 13 cu. ft. took place and was accompanied by a gradual increase in efficiency, raising removals to 60 per cent COD and 87 per cent suspended solids. It was concluded that the unit had been successfully put into operation without the use of seed sludge. In order to accelerate accumulation and determine performance at a higher sludge level, 200 gallons of digested sludge were added during the 10th week. The added sludge contained 192 pounds of total solids with a volatile content of 37.6 per cent.

Suspended solids tests show that during the year, 1780 pounds dry weight of solids were entrapped in the first tank; however, at the end of the period the tank had 65 cu. ft. of sludge with a total dry solids content of 305 pounds with a volatile content of 60 per cent. Measured gas production does not balance the amount of solids lost. An explanation of the small gas production has not yet been found.

It was originally felt that the sludge blanket would act as a combination of surface contact and distribution media. Model studies as well as pilot plant observation showed this not to be entirely true. The sludge particles tend to jell into a mass, and the incoming flow forms channels through the blanket. When sudden large increases in flow occur, the sludge blanket does not expand evenly. Rather, channels in the blanket are enlarged or changed and solids are carried into the liquid volume above the sludge zone. However, expansion of the blanket does occur when the flow is held constant at the increased velocity.

The sludge settling velocity is an important design parameter which is needed to determine the cross-sectional area in the upflow basin. Several models were constructed to determine at what flow the sludge would be held in suspension, but not be washed out of the tank. Because of the large range of sludge particle sizes, some solids were washed out at all tested flow, even down to velocities of less than 2 ft/day. Increases in flow wash out more solids at the beginning of the increase than in subsequent periods of sustained increased flow. Pilot plant operations substantiated these observations.

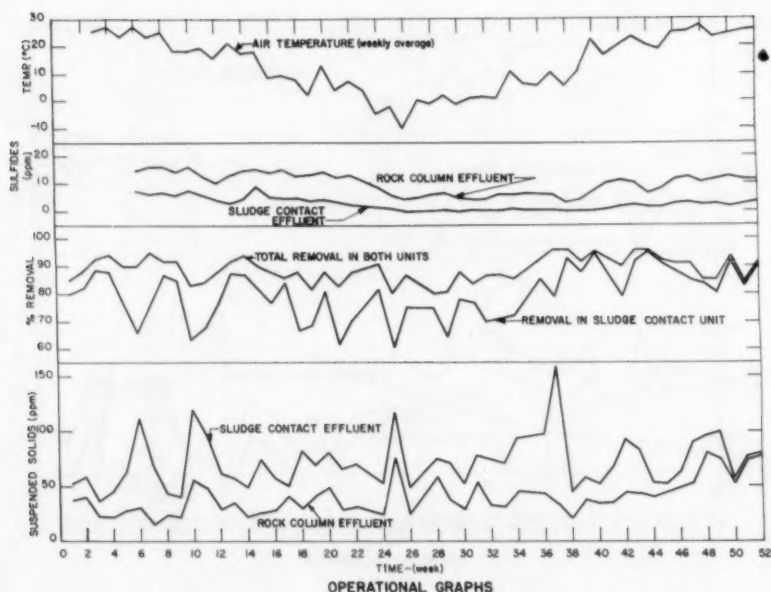


FIGURE 4

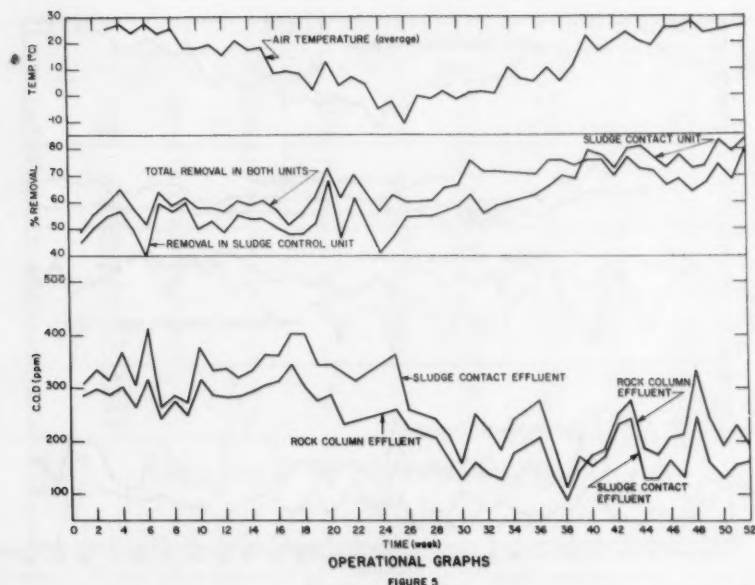
It was observed that below the upflow velocity of 15 ft/day, the sludge zone had a definite line of demarcation, but above that rate the sludge zone was less distinct and increase in the solids content of the effluent occurred. Several models and pilot plant studies have given this flow velocity figure. Model studies have dramatically shown sludge zone demarcation, and shock loading of the pilot plant has shown severe solid content increase in the effluent when upflow velocities of greater than 15 ft/day were applied.

Hydraulic Characteristics

Detention times and hydraulic characteristics of the primary tank have been studied in both the pilot plant and in various models. The theoretical detention time is 18 hours, which is based on the assumption of an orderly upward displacement of the liquid. The difference in temperature between tank liquor and incoming sewage, the sludge volume, and the shape of the tank all affect the flow pattern and the detention time.

The density difference, when the temperature of the incoming raw sewage is warmer than the liquor in the tank, causes a short circuiting. This is the typical case; when the tank liquor has cooled, warmer incoming sewage quickly rises to the surface, causing a noticeable decrease in the model detention of a dye tracer. However, when the raw sewage is cooler than the tank liquor, the density difference promotes an orderly upward displacement.

The increasing volume of the sludge continually decreased the displacement volume of the conical tank. The sludge zone assumed over one-third of the volume of the tank in a year. The volume of the sludge particles substantially decreased the liquid volume.



The sludge contact tank was given a conical shape for reasons of flow distribution, and for the testing of sludge settling velocity. However, model studies conducted on comparisons of flow characteristics between a conical and cylindrical shape tank show the expanding cross-section of the cone to be of no benefit in the distribution of flow.

The first studies were a series of the detention time of slugs of tracers in the pilot plant. Both fluorescein dye and radioactive tracers were used at different temperatures and flow rates. The results showed that shortcircuiting was occurring, and that its magnitude varied with temperature. The liquid temperature in the pilot plant tanks, which are located above ground, varied directly with the air temperature. Thus, the air temperature indirectly caused large changes in the detention characteristic of the flow.

An example of the detention of an instantaneous dosage of dye tracer in the pilot plant's primary tank is shown in Fig. 6. This curve shows the modal detention to be 3 hours, and the median detention to be 5 hours. First traces were seen in the effluent in 1-1/2 hours and last traces in 20 hours. The tracer used in this study was put in the primary tank when that tank was 1/3 full of sludge, with an average air temperature of 23° C, and a flow of 1.55 gpm.

In Table 2, the results of the series of tracer studies are given. It can be seen that short circuiting exists regardless of the temperatures or the sludge volume. However, the severity of short circuiting was increased, as can be seen by the decrease in the modal detention line, as the air temperature decreased. As the air temperature falls below the temperature of the warm incoming sewage, which is relatively constant, the liquid in the tank is cooled. The less dense warm sewage rises quickly to the outlet, causing the decrease

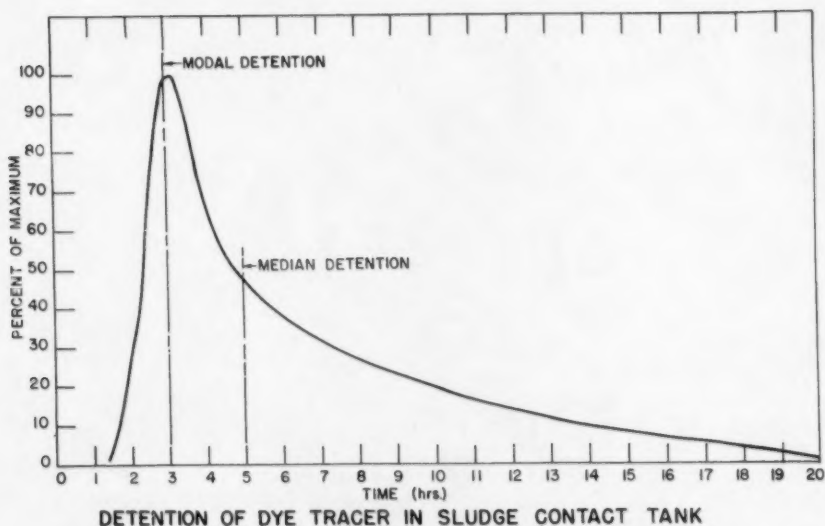


FIGURE 6

in the modal dye detention. The efficiencies in Column V and the "N" values show the increase in short circuiting with decreasing air temperature. Another factor can be noted from this table, the efficiency, based on the median dye detention, decreases as the volume of the sludge zone increases. All data presented are from tests in which virtually all the dye was recovered.

Observations of dye tracer in a model of a cylindrical tank and a conical tank were undertaken to determine the feasibility of the more economical cylindrical shape. The models were of identical height and the maximum cross-sectional area of the cone was equal to that of the cylinders. The slope of the cone was 60° with the horizon, identical to the pilot plant installation. A second cylindrical model was used with the previous cross-section, but with only one-third the height giving a volume equal to that of the cone. Dye detention was greatly affected by thermal density currents in the liquids. Detention of the dye was mainly a function of volume when favorable thermal gradients existed. Height and shape had little effect on the detention; however, multiple outlets had a beneficial effect by reducing the "dead area" caused by a single outlet. When the unfavorable thermal condition of warmer incoming liquid existed, dye detention was neither a matter of shape or height and volume played a minor part. The thermal density difference was the controlling factor in all models.

The Rock Column Unit

Past experience with other anaerobic processes made it seem probable that the primary unit would be subject to periodic disturbances resulting in loss of solids. For this reason, and because of a desire for additional treatment, an anaerobic rock column was incorporated into the treatment process. The use

TABLE 2
DYE TRACER STUDY RESULTS

I	II	III	IV	V	VI	VII	VIII	IX
Date	Air Temp °C	Theoretical Detention* Hours	Modal Dye Detention Hours	Efficiency $\left(\frac{IV}{III}\right) 100$ %	"N" $\left(\frac{VIII}{VIII-IV}\right)$ %	Sludge Zone Volume Ft ³	Median Detention Hours	Efficiency $\left(\frac{VIII}{III}\right) 100$ %
9-5-57	29.5	18.	8.0	44	3.9	7.4	10.8	60
10-8-56	20.5	19.	5.0	26	2.0	23.5	10.0	53
1-10-57	-2.8	9.	1.0	11	1.2	39.0	5.2	58
2-5-57	1.0	18.	2.5	14	1.3	62.0	9.8	54
7-17-57	23	13.	3.0	23	2.5	72.0	5.0	38

*Theoretical Detention = volume of cone \div flow (have disregarded sludge zone volume)

of a rock media was decided upon to provide surface area for additional treatment and to act as an agitator on any gas laden particles carried from the first unit.

In the laboratory, the rock column was observed to be free from maintenance requirements and to provide additional treatment. Solids removal was evident in the unit. Plugging was shown to be unlikely as the entrapped solids were easily drawn off when the unit was dismantled. In the laboratory the rock column and the sludge contact tank were tested as a combined unit.

The rock column as installed in the pilot plant is shown in Fig. 1. The rock medium in this column is 4' in depth and has a 4' x 4' cross-section. The rock is 1-1/2" to 2-1/2" in size and is a river deposit gravel. There is a 1-1/4' liquid depth over the rock and 1' height of distributing volume below the rock. The total liquid volume is 410 gallons. Flow from the first unit enters the column at the bottom and flows upward through the rock to a weir outlet at the top which is protected by a scum baffle.

Suspended Solids; COD and BOD Removal

The operational data of the rock column have been collected and analyzed as an individual unit in the pilot plant study. The BOD and COD had the linear relationship expressed earlier. Weekly averages of the daily analysis are tabulated in Fig. 3, and shown combined with the sludge contact unit in Figs. 4 and 5. Figs. 4 and 5 show the contribution of the rock column as a part of the process for disposal. COD and suspended solids strengths vary less in the influent and effluent of the rock column than in the raw sewage. In Fig. 5, the rock column shows ability to remove additional solids. This fact is most significant when solids in the primary effluent suddenly increase. In the testing procedure, several major disturbances were caused in the sludge contact unit which resulted in an increased amount of solids in the influent of the rock column. The rock column effectively reduced these solids to a more constant strength level in the final effluent.

TABLE 3 - ROCK COLUMN TANK

Months	Weeks	Suspended Solids			COD			Sulfides	
		Inf	Eff	% Removal	Inf	Eff	% Removal	Inf	Eff
July-Oct.	0-15	66	32	51	327	287	12	6.2	14.5
Nov-March	16-36	73	39	47	293	226	23	1.8	8.7
Apr-July	37-52	77	51	34	171	205	-20	1.8	9.4
July-July	0-52	72	41	43	263	237	10	2.8	10.2

Table 3 gives the average of results for the year and for the three previously defined periods. The yearly average was 10 per cent COD removal. The COD removal varied with temperature with a removal of 23 per cent in cold weather and a minus 20 per cent during warm weather. This decrease of COD removal was accompanied by a large gas production causing an increased carry-out of solids in the effluent.

Suspended solid removal averaged 44 per cent in the tank over the year. The removal of suspended solids did not vary as greatly with temperature as did the COD removal. However, suspended solids increased in the effluent during warm weather after rapid gas production started. Table 3 shows a decrease in suspended solid removal from 47 per cent during cold weather to 34 per cent during warm weather.

The COD and the suspended solids removals were influenced by the production of gas during the warm weather. However, this disturbance could have been eliminated by removing the solids that accumulated over the winter months before they caused an upset in the tank.

The sulfides averaged, in Table 3, were 10.2 ppm over the year in the rock column, which is a threefold increase in magnitude over the 2.8 ppm average of the contact tank. The highest concentration of sulfides coming from the rock column was 17 ppm, which presented an odor problem. In Fig. 4, the variations in the sulfide concentrations are shown.

Depth of Rock

An attempt was made to improve the performance of the rock column by increasing the depth of media. During the fall a small laboratory rock column of 3 inch diameter was added in series and the flow rate adjusted so that up-flow velocity would be equal to that in the larger unit. The purpose of this study was to see if the doubling of the rock depth to 8' was beneficial and justifiable. There was a corresponding improvement in removal of COD; however, the suspended solids were consistently greater in the effluent. It was decided that this additional rock depth was not justifiable. This small column gave the first suspicion that unloading was likely to occur in the secondary unit.

CONCLUSIONS

1. Analysis of laboratory and pilot plant data shows that the anaerobic contact process provides substantial removal of organic matter.
2. For the year's operation, removal of 83 per cent suspended solids and 62 per cent COD were obtained in the anaerobic sludge contact tank with an inoffensive sulfides concentration of 2.8 ppm in the effluent.
3. In the sludge contact unit, gas production was small with little or no methane developed. There was an absence of a scum formation or spring upset in this unit.
4. The upflow of sewage forms channels through the sludge. Sudden large increases in flow wash some solids out of the blanket of sludge; however, sustained increased upflows of 15 ft/day or less give satisfactory sludge detention.
5. Thermal-density differences greatly affect detention time. If conditions warrant, the tanks should be placed below ground to minimize unfavorable liquid density differences.
6. The expensive conical shape of the pilot plant sludge contact tank has no advantage in comparison with a cylindrical shape in flow distribution. Multi-outlets were found to have a beneficial effect by reducing the "dead areas" caused by the single outlet in the pilot plant sludge contact tank.

7. The anaerobic upflow rock column has removed 44 per cent of suspended solids and 10 per cent COD; discharging an odorous effluent with 10.2 ppm of sulfide for the year's operation. Odor would make the use of the rock column unit objectionable in the immediate vicinity of a subdivision. However, COD removal efficiency would be increased to 20 per cent by a yearly spring cleaning.
8. Doubling the depth of media in the rock column is not justified by a corresponding improvement in removal efficiencies.

SUMMARY

An anaerobic process for suburban sewage treatment using an upflow sludge contact unit and an upflow rock column unit has been tested in a pilot plant installation. The installation had a total liquid capacity of 222 cu. ft. and was operated with a 24 hour detention at a constant flow. Domestic sewage with an average strength of 695 ppm of COD and 429 ppm of suspended solids was used as a feed.

The combined units removed 91 per cent of the suspended solids and 66 per cent of the COD. The final effluent contained an average strength of 237 ppm of COD and 41 ppm of suspended solids. The anaerobic sludge contact unit did the majority of the work in producing an effluent with an average strength of 72 ppm of suspended solids and 263 ppm of COD. A linear relationship existed between the BOD and COD. There was an absence of a scum formation, offensive odors, or spring upset in the sludge contact unit.

The simplicity of design and absence of moving parts give promise of low initial and maintenance costs. The operational data show an efficient process for suburban sewage treatment.

ACKNOWLEDGMENT

Professor Don E. Bloodgood reviewed this paper. Mr. R. T. Shibiya did much of the analytical work, and Mr. N. McGuire operated the pilot plant.

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1. The first part of the paper discusses the importance of the study of the history of the United States. It is argued that a knowledge of the past is essential for a full understanding of the present and for the development of a sound policy for the future.

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AN ANALOG COMPUTER FOR THE OXYGEN SAG CURVE

Morton D. Sinkoff,¹ J. M. ASCE, C. Don Geilker,² and Jan G. Rennerfelt³
(Proc. Paper 1850)

INTRODUCTION

High speed electronic computers are presently revolutionizing many phases of engineering and may be expected to have numerous applications in the field of sanitary engineering. Attention has recently been directed to the development of an analog computer for use in the specific area of stream pollution computations.

Although the theory of an analog computer is relatively simple, the application of an electrical analogy in the field of stream pollution is new. The purpose of this paper is to present the theory of such an application in a form useful to sanitary engineers.

Background

The proposal that an analog computer could easily be adapted to solve the Streeter-Phelps Oxygen Sag Equation⁽¹⁾ was first presented by Rennerfelt⁽²⁾. Detailed from Sweden to the Robert A. Taft Sanitary Engineering Center in Cincinnati during 1957 to observe American approaches applied to stream pollution problems, Mr. Rennerfelt suggested the use of an analog computer in the solution of the basic BOD vs. time relationship as well as in the solution of the Oxygen Sag Equation. His ideas were followed in the development and construction of a computer which, unfortunately, was not completed and tested until after his return to Sweden.

Note: Discussion open until April 1, 1959. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 1850 is part of the copyrighted Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 84, No. SA 6, November, 1958.

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Theory

The theory about to be presented describes an analog computer that may be used for the solution of equations having the general form:

$$\frac{dY}{dx} + f_1(x)Y = f_2(x)$$

Persons familiar with stream pollution problems will recognize the more specific form (see reference 1) of this linear differential equation of the first order:

$$\frac{dD}{dt} = K_1L - K_2D$$

in which:

- t = Time of reaction.
- L = Oxygen demand of organic matter.
- D = Oxygen saturation deficit of the water.
- K₁ = Rate of deoxygenation.
- K₂ = Rate of reoxygenation.

An electrical analogy describing this equation will now be developed.

The current through a resistor and the voltage across a capacitor, in a resistance-capacitance circuit, have exponential time histories. Both the exertion of BOD and recovery from oxygen depletion are similar functions with respect to time. This suggests that the stream variables may be represented by an electrical circuit of the type shown in Fig. 1. Referring to this figure, when switch S₁ is closed (S₂ remaining open) the current charging the capacitor, measured through the resistor, is given by

$$I = \frac{E}{R} e^{-\frac{t}{RC}} \quad (1)$$

in which

- I = current in amperes.
- E = potential in volts.
- R = resistance in ohms.
- C = capacitance in farads.
- t = time, in seconds, since closing of switch S₁.
- e = base of natural logarithms.

A plot of equation (1) is shown in Fig. 2. For the same situation, the charge (voltage) buildup across the capacitor is given by

$$Q = EC \left(1 - e^{-\frac{t}{RC}}\right) \quad (2)$$

where Q = charge on the capacitor and is shown schematically in Fig. 3.

Now, with S₁ open and S₂ closed, the plot of current discharge is the same as in Fig. 2 (with the sign reversed), and the equation for voltage discharge

$$\frac{Q}{C} = E e^{-\frac{t}{RC}} \quad (3)$$

is similar to (1) as is shown in Fig. 4.

E_1 = POTENTIAL (VOLTS)
 R_1 = RESISTANCE (OHMS)
 C_1 = CAPACITANCE (FARADS)
 S_1 & S_2 ARE SWITCHES

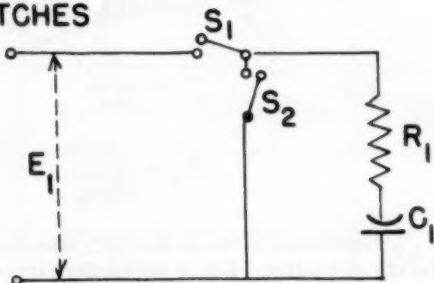


FIG.1. AN R-C CIRCUIT

Application to the Oxygen Sag Equation

Should a recorder of some type be included in the circuit shown in Fig. 1 and a plot of the transient current (or voltage) displayed, the circuit may be used as a model to describe functions of the exponential type. It is possible to combine the simple circuit with others of the same type to display curves of a more complex nature. An analysis of the oxygen-sag curve shows that an electrical model may be constructed using only two of these circuits, as explained in the following discussion.

The usual form of the oxygen-sag formulation as integrated is given by Equation 4:

$$D_t = \frac{K_1 L_a}{K_2 - K_1} (e^{-K_1 t} - e^{-K_2 t}) + D_a e^{-K_2 t} \quad (4)$$

where D_t = Oxygen deficit at time t .

K_1 = Rate of deoxygenation.

K_2 = Rate of reoxygenation.

D_a = Initial oxygen deficit.

e = Base of natural logs.

L_a = 1st stage BOD of organic matter present.

Rearranging terms,

$$D_t = \left(\frac{K_1 L_a}{K_2 - K_1} \right) e^{-K_1 t} + \left(D_a - \frac{K_1 L_a}{K_2 - K_1} \right) e^{-K_2 t} \quad (5)$$

The similarity of each component of the right side of Eq. 5 to the right side of Eq. 1 is the basis for the electrical analogy to the oxygen sag equation (cf. Figs. 5, 2). Two circuits combined in the proper sense will yield the "sag" curve. That is, let

$$\frac{E_1}{R_1} = \alpha_1 \left(\frac{K_1 L_a}{K_2 - K_1} \right) \quad (6)$$

$$\frac{E_2}{R_2} = \alpha_2 \left(D_a - \frac{K_1 L_a}{K_2 - K_1} \right) \quad (7)$$

$$K_1 = \frac{1}{R_1 C_1} \quad (8)$$

$$K_2 = \frac{1}{R_2 C_2} \quad (9)$$

where $\alpha_{1,2}$ represents a "scale factor", then equations 6-9 define the analogous electrical system. Fig. 6 shows the circuit wired to record transient current. The recorder, thus wired, will plot the oxygen sag curve to some arbitrary scale.

For experimental verification, a trial analog was constructed and a series of plots displaying the "sag" curve were obtained. An initial deficit of 1.5 ppm and several values of K_1 and K_2 were assumed. These quantities were adjusted manually by varying the proper electrical quantity, a switch was thrown closing both circuits simultaneously, and the recorder began plotting a "sag" curve. A photograph of one of these curves is shown in Fig. 7. The resulting values of critical deficit and time were obtained directly from the

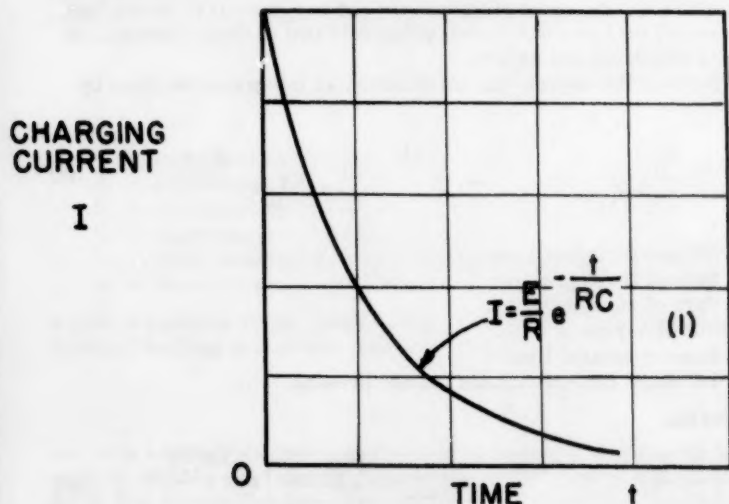


FIG. 2. CHARGING CURRENT IN R.C. CIRCUIT

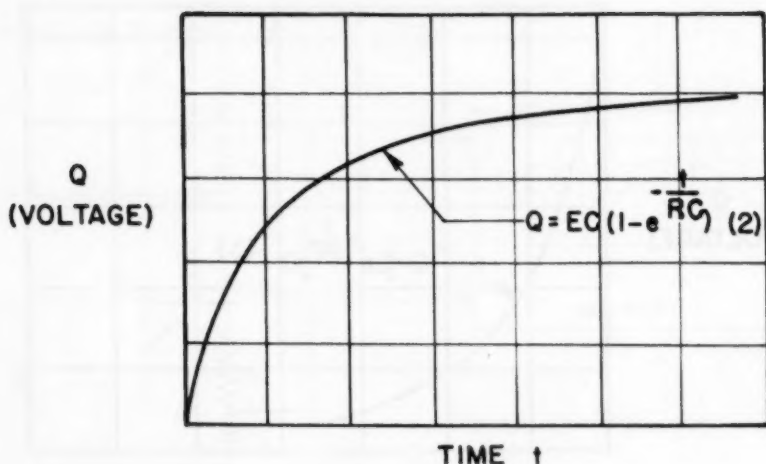


FIG. 3. CHARGE BUILDUP ON A CAPACITOR

plot as well as a derived value of L_a . L_a was derived by substituting in Eq. 4 the quantities K_1 , K_2 , D_a , (constants set on the analog) and a value of D_t and t from the analog plot (Fig. 7) and solving for the remaining unknown, L_a . Eight different values of D_t and the corresponding time (t) were used, with the result that L_a ranged between 19.3 and 21.3, averaging 20.0. This small variation is evidence that the electrical curve closely approximates the corresponding mathematical expression (Eq. 4). It is interesting to note that once the "scale factors" have been evaluated L_a may be obtained by solution of Eq. 6 or 7.

Future Plans

The possibilities of an analog of this type as an aid in stream computations seem to be extensive. Therefore, since the model analog was a success, a more comprehensive and versatile instrument is now under construction.

This instrument will be used to determine the feasibility of deriving K_1 , K_2 and L_a directly, in a matter of seconds, from dissolved oxygen data obtained from a carefully controlled river survey, with a minimum of laboratory work. That is, the constants will be evaluated from the oxygen sag curve by means of the analog, fitting the electrical curve to the actual curve and reading the constants directly from the analog.

Since many different sag curves may be plotted in a relatively short time, the analog computer would appear to have value as a tool for predictive purposes. With a given set of conditions as obtained from field data, predicted conditions may be introduced into the analog and a new "sag" curve rapidly plotted or a new K_2 predicted, etc. A catalog of many such curves showing the effects of varying K_1 and K_2 through wide ranges could easily be obtained. Such a catalog would be useful in the derivation of a goodness-of-fit test so

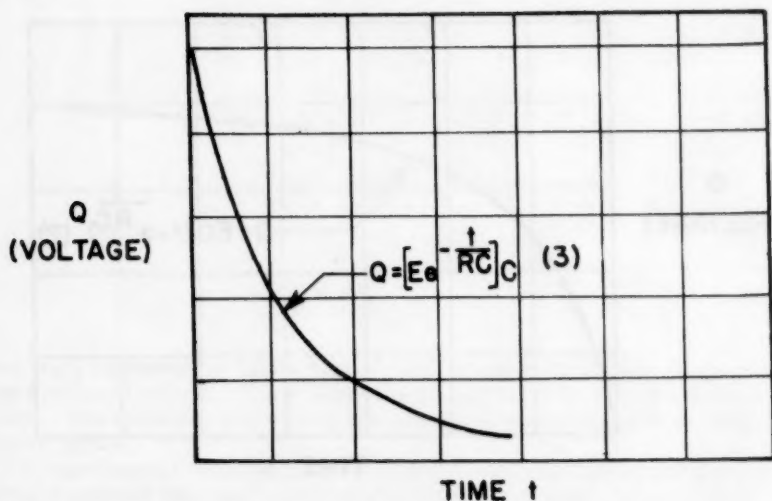


FIG. 4. CAPACITOR CHARGE DURING UNLOADING

that the adequacy of the curve obtained by the analog from raw data might be assessed objectively.

The instrument will be constructed flexible enough so that varying rates of reaction (K_1, K_2) may be introduced in the plotting of any one sag curve.

Research in all the above phases is planned as part of the over-all adaptation of the analog computer to stream pollution computations.

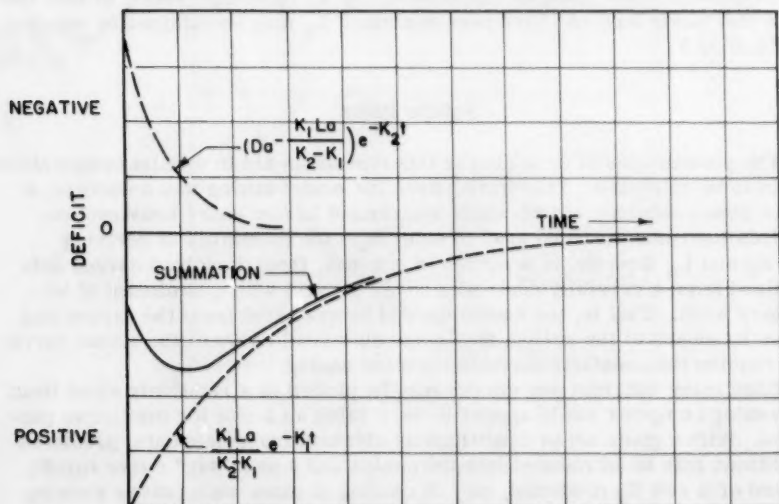


FIG. 5. SEPARATE COMPONENTS OF SAG CURVE

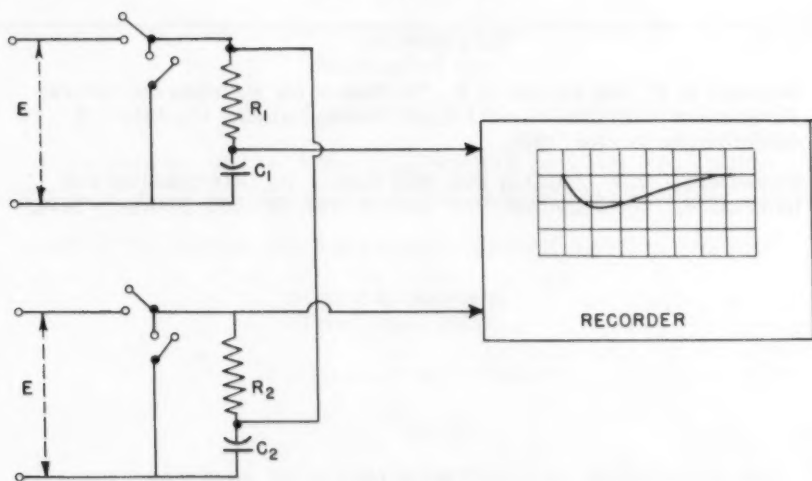
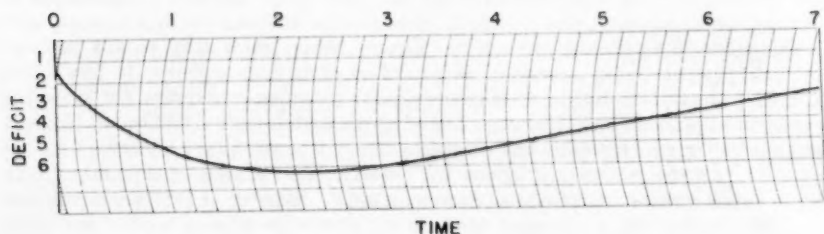


FIG. 6. THE ANALOG FOR THE "SAG EQUATION"

ACKNOWLEDGMENT

The authors wish to express their gratitude to Mr. Ralph Porges, In Charge, Waste Treatment Studies and Dr. William M. Ingram, Biologist, both of the Water Pollution Control Section, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, for their aid in the preparation of this paper.



PRESET QUANTITIES:

$D_0 = 1.5 \text{ ppm}$
 $K_1 = 0.143$
 $K_2 = 0.217$ } BASE 10

DERIVED QUANTITIES:

$D_c = 6.3 \text{ ppm}$
 $t_c = 2.3 \text{ units}$ } OBSERVED
 $L_0 = 20 \text{ ppm}$ } COMPUTED

FIG. 7 PHOTOGRAPH OF SAG CURVE PLOTTED BY RECORDER

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Proceedings of the American Society of Civil Engineers

ADMINISTRATION OF AIR POLLUTION CONTROL LAWS IN OREGON^a

Richard E. Hatchard¹
(Proc. Paper 1851)

ABSTRACT

The paper relates the background of the Oregon Air Pollution Authority and its relationship with local agencies. It discusses prevention and current needs as well as the role of the engineer in air pollution.

INTRODUCTION

Many Civil Engineers have not had frequent contact with air pollution problems so a few definitions may be of help to understand what is being done in the Oregon program. One widely accepted definition of air pollution is⁽¹⁾ "the presence in the outdoor atmosphere of one or more contaminants such as dust, fumes, gas, mist, odors, smoke or vapor in quantities of characteristics and of duration such as to be injurious to human, plant, animal life, property, or which unreasonably interferes with the comfortable enjoyment of life and property". This definition is based upon undesirable effects produced by the excessive emission of air contaminants and does not imply that the use of the atmosphere should be restricted for waste disposal unless an undesirable effect is created. This approach is identical to some water pollution control programs where the dilution capacity of the stream, the biological recovery cycle, and the present and future stream uses are all considered when an additional effluent is being proposed for discharge into public waters. The emission of waste products into the atmosphere is not a new phenomena but one that has been with us for hundreds of years; so why has interest in air pollution increased greatly in the past ten years? The answer to this question will be found in statistics showing the industrial and population growth in the U. S. During the period⁽²⁾ 1940-1950 industrial production has about tripled and the population of 151 million in 1950 is

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- a. Presented at the June, 1958 ASCE Convention in Portland, Oregon,
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expected to grow⁽³⁾ to 190 million by 1965. Another primary factor is the shift of our population from agricultural areas to urban communities.⁽²⁾ In 1900 56% of the population lived on farms but by 1950 60% of the population were residents of urban communities. These changes have greatly increased the total quantity of discharges being released into the air while the ability of the atmosphere to satisfactorily dilute these materials is definitely limited by local meteorological conditions.

Community Air Pollution Factors

The emissions from industrial processes are not the only major sources of community air pollution problems. The public frequently does not understand this fact. It is true that industrial discharges from steam generating plants, electric furnaces, smelting, mixing, grinding, crushing, solvent evaporation, and similar operations are usually the largest individual discharge sources in a community. The total discharge, however, from hundreds of stacks for space heating and refuse incineration from commercial activities become another major source. The atmospheric discharges from the individual citizen is the third major community source and includes vehicle exhaust, refuse disposal, and, in some communities, space heating discharges.

There are two general types of air pollution problems; an area-wide situation created when the total of the atmospheric emissions exceed the ability of the atmosphere to satisfactorily dilute the contaminants, and a local problem downwind from an identified source or sources which affects a relatively small part of the community. It is evident that the variables involved in the large area problem are many and require intensive investigations to develop controls that will meet the local conditions. On the other hand, the control of a single source or a few identified sources can usually be solved by operational changes or by the installation of adequate control system.

Another complicating factor is the lack of accepted standards to identify concentration values of specific air contaminants which, if exceeded, will create injury or public nuisance. In addition, a variety of methods are used to collect and analyze similar air contaminants which frequently limit the validity of comparing data.

Oregon Air Pollution Authority

In 1950 the Governor's Committee on Natural Resources recognized that the predicted population and industrial growth in Oregon would adversely affect the air resources of the state unless a prevention and control program was undertaken. The 1951 Legislature created the Air Pollution Authority as a Division in the State Board of Health to fill this need. This⁽⁴⁾ statute provided a separate policy making board composed of the State Health Officer, one member of the Sanitary Authority which is the water pollution control agency, and three other members appointed by the Governor for four year terms. The State Sanitary Engineer serves as Secretary. The statute was patterned after the successful water pollution control program and authorized a statewide study and control agency to carry on the following activities:

1. Develop a comprehensive program for the prevention and control of all sources of pollution of the air of the state.

2. Advise, consult, and cooperate with other agencies of the state, political subdivisions, industries, other states, the Federal Government, and with affected groups in furtherance of the purposes set out in ORS 449.710.
3. Encourage and conduct studies, investigations, and research relating to air pollution and its causes, prevention, control, and abatement, as it may deem advisable and necessary.
4. Collect and disseminate information relating to air pollution, its prevention and control.
5. Promulgate rules and regulations.
6. Consider complaints, make investigations, and hold hearings.
7. Require any person to submit plans for the removal of air contaminants.
8. Encourage voluntary cooperation by the people, municipalities, counties, industries, and others in restoring and preserving the purity of air within the state.
9. Employ personnel, including specialists and consultants, purchase materials and supplies, and enter into contracts necessary to carry out the purposes set out in ORS 449.710.
10. For the purpose of investigating conditions relating to air pollution, through its members or its duly authorized representatives, enter at reasonable times upon any private or public property, except private dwellings.
11. Enforce compliance with the laws of this state relating to pollution of the air.
12. Represent the State of Oregon in any and all matters pertaining to plans, procedures, or negotiations for interstate compacts in relation to control of air pollution.

A biennial budget of about \$120,000 is provided for a staff consisting of four engineers, two chemists and one stenographer. Initially an extensive air sampling program was undertaken to determine the existing atmospheric pollution levels in the Oregon community. Even before a technical staff was employed a relatively large number of complaints had been received regarding specific problems.

Local Programs

The Air Pollution Authority recognized that it was not the intent of the Legislature that all air pollution problems within the state be administered by the state agency. An effective control program involves the regulation of a large number of air pollution sources within the city boundaries such as industrial processes, space heating, refuse disposal, and vehicle exhaust. Many of these sources can not be regulated directly by a state agency and can be administered more efficiently by an adequate community air pollution program. In order to encourage the organization of local programs the members of the Authority announced that their policy regarding their relationship to municipalities would be:

1. To preserve and encourage local autonomy on matters of air pollution control to the extent that cities would be expected to carry on local programs for air pollution control with such technical assistance and advice from the Authority as may be necessary.

2. To cooperate with cities in the furtherance of local air pollution control programs.
3. To collect and disseminate information to cities on prevention and control of air pollution.

The initiation and expansion of municipal programs in Oregon has proceeded at a slow rate. However, the cities of Eugene (population approximately 50,000) at Klamath Falls (population approximately 20,000) passed ordinances in 1956 and have local efforts underway. The health officer of the City of Portland has requested funds to employ a technical staff to increase the activities now carried on a part time basis. It is hoped that city officials of Oregon's largest city will provide funds and adopt appropriate ordinances soon to support an effective air sanitation program.

It is doubtful if cities of less than 10,000 population would be able to administer their own programs. However, most cities with populations between 10,000 and 100,000 could carry on a successful program with a varying amount of technical assistance from the Air Pollution Authority. For cities larger than 100,000 the staff and ordinance provisions should allow the city officials to administer the program within the city boundaries with assistance from the Authority on regulations, unusual technical problems, and control activities in the urban fringe.

Control Actions

Since 1952 the Air Pollution Authority has pursued a program which has resulted in installation of control systems costing over four million dollars, mostly serving industrial operations. In these efforts several types of actions have been applied to bring about solutions to air pollution problems. A cooperative approach is the first step undertaken to solve an air pollution problem.

One example is the manner in which control of the cement dust deposition problem at a mill in Oswego, which is about eight miles south of the Portland city limits, was handled. The cement plant was originally located in an industrial area but the business and residential community is now located less than one-quarter mile away. Many complaints were filed with the Authority regarding the deposition of cement dust over a large area. The Oswego City Council also requested the Air Pollution Authority to investigate the problem and bring about control.

After intensive field surveys and analyses of air sample data, recommendations were made to the company management regarding additional dust collection equipment needed to prevent nuisance conditions. The company obtained additional stack sample measurements and retained consultants to design the control facilities. Agreements were reached in conference regarding the degree of reduction needed to remove public nuisances and the Air Pollution Authority approved the plans and specifications for the installation of additional electrostatic precipitation and other control facilities which cost about \$700,000.

In instances where reasonable progress is not made in the correction of an air pollution nuisance the members of the Authority call a public hearing and enter an order based upon the evidence produced. During six years of the program, the Authority has applied enforcement proceedings in only five cases. An example of this action involved an asphalt paving contractor located in a southern Oregon community. Complaints were filed by nearby residents

that the dust and asphalt vapor from a portable paving plant operations were causing public nuisance. Field investigation established that public nuisance was present and recommendations were made to the paving plant owner. No other action was taken toward control and the Authority members requested the State Attorney General to enforce the provisions of the statute. When an injunction was obtained in the Circuit Court the paving plant owner then installed the necessary control equipment and continued his operations without causing further public nuisance.

Preventing Air Pollution

The prevention of an excessive discharge into the atmosphere is one of the most important aspects of the Authority's control program. The Authority has required that plans for major new industrial plants or expansions of existing operations be reviewed if a significant atmospheric discharge is involved. This activity has been undertaken jointly with the local agencies concerned. An example is the new Georgia-Pacific Corporation's 250 ton per day kraft mill in Toledo which started production earlier this year. While the plant was still in design stage members of the Air Pollution Authority's staff conferred with the firm's engineers and management representative regarding the control measures needed. The plans and specifications for the facilities were reviewed and approved before the plant began production. Initial controls included facilities for particulate recovery and special odor control systems to minimize the characteristic odor from the kraft process at a cost of approximately \$300,000.

Due to the incomplete meteorological data available it was not possible to be assured that excessive odor would be prevented at all times. However, the Authority and the company management realizes that facilities for complete odor reduction for a kraft mill are still in the stage of development and additional controls may be needed in the future.

The Planning and Zoning agencies are becoming increasingly interested in the factors of air pollution which affect their land use programs. There is a definite trend toward development of performance type regulations instead of the traditional limitation by type of industrial or commercial activity.

The Authority has adopted regulations that define some of the measurements to establish whether an air pollution problem exists. These include deposition rate, suspended particulates, smoke discharge, and lime dust. These regulations may be used as a guide for planning and zoning organizations to determine if a particular location can accommodate an additional atmospheric discharge. Obviously other regulations or standards are needed for many other types of air contaminants to adequately serve this purpose.

In the past, control programs have relied primarily upon source discharge limits alone but the Authority has found that satisfactory control must consider the local conditions. These factors include data regarding air pollution caused by existing discharges, future growth, meteorology, topography, and land use. There is a critical need for regulations or standards defining acceptable air contaminant concentrations in the community atmosphere that will prevent injury or public nuisance. Area concentration standards for common contaminants such as sulfur dioxide, oxidants, acid mists, oxides of nitrogen, fluoride, and others could then be objectives for control agencies and planning and zoning programs.

Current Needs

The needs in Oregon to assure effective air sanitation includes the following:

1. Organization and expansion of municipal programs.
2. Public education to obtain understanding that all community sources must be controlled.
3. The human health aspects of air pollution must be defined and additional correlations are needed to establish the specific nature of the large scale economic loss.
4. More emphasis should be given to the prevention of air pollution and an increase in activities is needed by the local planning and zoning agencies.
5. Increased efforts towards the development of adequate control facilities to serve certain industrial processes and public sources such as refuse disposal.
6. More local consulting engineering services are needed to perform measurements of specific emission and to design control facilities.

The Engineering Role

The organization and administration of successful state and local programs will rely heavily on many types of engineers. The sanitary engineer is vitally concerned with this aspect of the environment and is in a position to apply some of the approaches developed in other environmental sanitation activities that have proven successful. In addition broad aspects of air pollution will require contributions from many professions including agricultural, public administrators, law, medicine, meteorology, statisticians, chemists, and other scientists. It is frequently the sanitary engineer who must supervise the local and state air sanitation efforts which involve complex administrative relationships. The engineer must bring together the complex technical data to create a successful program and concurrently maintain education and support of the public.

SUMMARY

Summarizing the main points based upon the Oregon program are as follows:

1. The growth of population and industry is over-taxing the ability of the atmosphere to carry off waste products without producing public nuisance.
2. The prevention and control of pollution requires the support and actions of the public along with the industrial and commercial part of the community.
3. Most air pollution nuisances created by a single source, or a few identified sources, can be effectively controlled with available methods. The community-wide problem caused by a mixture of hundreds, and in some cases thousands, of anonymous sources present a challenge to engineers and others.

4. Nineteen states are now carrying on study for control programs and in the near future many other states will join the effort. The increase in state activity will never prove to be a substitute for local air pollution programs.
5. In Oregon the correction of excessive air pollution sources has involved the expenditure of over four million dollars.
6. Regulations have been formulated which define some of the air pollution contaminant concentrations that will produce public nuisance based on extensive measurements in Oregon.
7. Additional regulations or standards are needed to define the allowable concentration of air contaminants in the community atmosphere that will prevent injury or public nuisance.

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MUNICIPAL COMPOSTING IN THE UNITED KINGDOM

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(Proc. Paper 1852)

Composting of refuse and sewage sludge is receiving attention as a feasible method of waste disposal. Two municipal composting plants operating in the United Kingdom are described in detail. The general trend in refuse disposal is outlined, and other composting plants making a contribution towards the development of composting are mentioned.

INTRODUCTION

A large amount has recently been written about composting and most readers will be familiar with the process. However, for those who have not been introduced to composting, a brief explanation of the process is included.

Process

Composting is a process of decay in which organic matter decomposes under the action of bacteria, fungi, moulds and other organisms. The requirements of these organisms are food, air and moisture, supplied in an environment which allows a slight thermal insulation. Waste organic matter supplies the food; its decomposition proceeds at a rate corresponding to the degree with which favourable conditions of aeration, moisture and temperature are maintained in the material. The organisms transform unstable organic material, which may often be offensive; into an innocuous compost. The time for this transformation varies; if left entirely to Nature, a year or more is required, whereas it is only a matter of days when modern techniques are employed. Compost, a humus-forming material, resembles earth in appearance and odor and has considerable value as a soil conditioner and fertilizer.

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Application

When the composting process is applied to town wastes, the term municipal composting is often used. The two most important town wastes are refuse (garbage and trash) and sewage, the latter often including industrial wastes. The disposal of these wastes presents a problem to municipal authorities who must deal promptly with the wastes if modern conditions of hygiene and cleanliness are to be attained. The application of composting treatment to town wastes is shown diagrammatically in Fig. 1.

Composting in the United Kingdom

Some early attempts of municipal composting were failures which has tended to dampen enthusiasm towards composting in this country. The lack of knowledge about the process together with difficulties in marketing the product were the main reasons for failure. Conditions over the last twenty-five years have changed. The value of certain items in refuse now makes separation and salvage a desirable feature of many refuse disposal schemes. The practice of controlled tipping (sanitary landfill) is on the decline in many places due to the decrease in available space and increase in haulage distances. Incineration is expensive and is being discouraged with the present campaign against atmospheric pollution. Perhaps the most important change to encourage the adoption of composting treatment is the recent trend towards the use of organic fertilizers in agriculture.

The general attitude towards composting in the U. K. is that it is regarded as a disposal method; it is not looked upon as a profitable operation which will attract private capital and consequently the economics of composting are compared against those of other disposal methods.

In certain cases, composting treatment has simultaneously solved the problem of refuse and sewage sludge disposal and at the same time obtained the most beneficial re-use of the waste materials. Hygienic conditions are usually improved when composting treatment is applied. The functional aspects of composting have proved satisfactory and it is the economic aspects which are now under test. The economic picture of plants described in this paper are individually discussed.

Refuse

Refuse accumulates at approximately 1.5 to 2.0 lb per-person-per-day in the U. K. The average percentages by weight of the various items in the refuse are given in Table 1. The largest seasonal variation is with the dust which can change from under 30% by weight in the summer to over 50% by weight in the winter.

Sewage

The practice of sewerage in the U. K. generally follows the same lines as in America. Sewage treatment works usually include primary sedimentation, biological treatment and final sedimentation; the sludge is air dried in drying beds or shallow lagoons. In the larger works, sludge digestion is employed and the evolved gas is used for power generation. The air drying of sludge

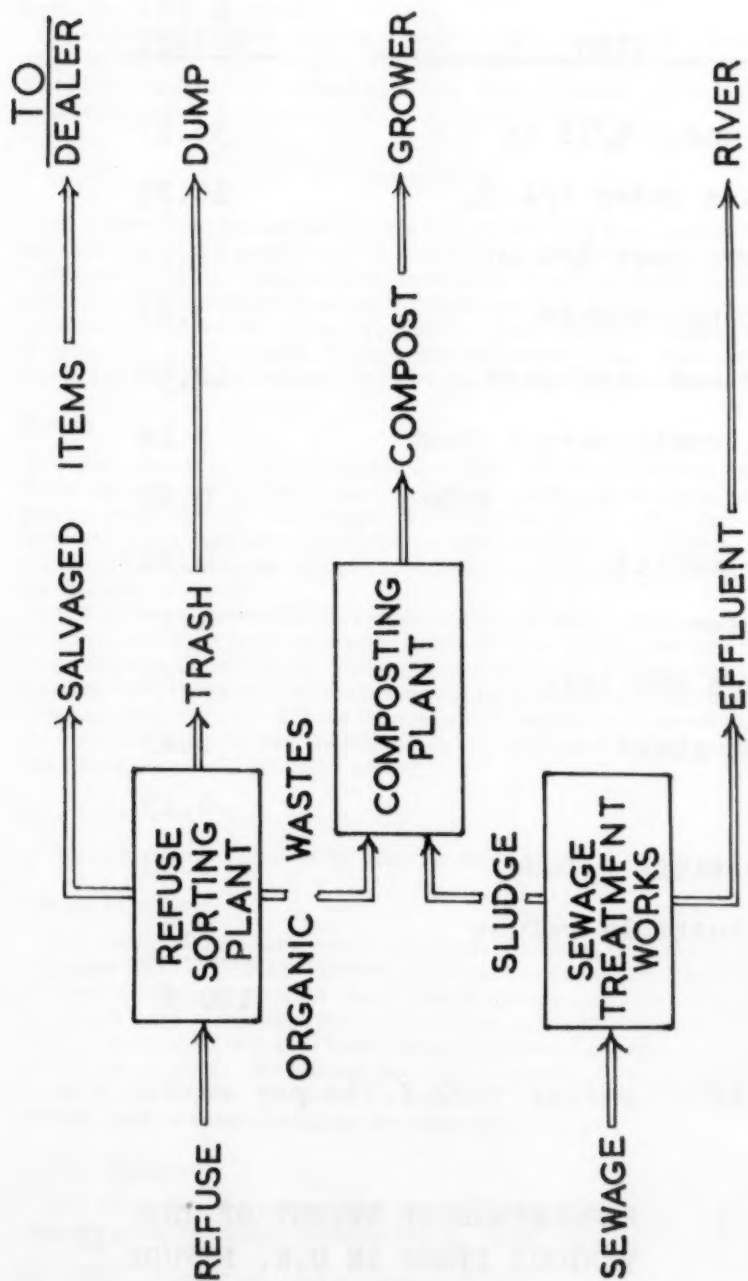


FIG. 1 APPLICATION OF COMPOSTING TO TOWN WASTES

<u>ITEM</u>	<u>% BY WEIGHT</u>
Dust under 5/16 in	36.11
Cinders under 3/4 in	16.75
Cinders over 3/4 in	12.23
Vegetable matter	3.43
Paper and cardboard	12.38
Metal containers - food	3.14
" " - other	0.60
Other metals	0.91
Textiles	1.27
Bottles and jars	2.84
Broken glass	2.42
Bones	0.29
Combustible refuse	2.08
Incombustible refuse	5.55
	<hr/>
	100 %

Density of refuse = 20.7 lbs per cu ft

Table 1 PERCENTAGE BY WEIGHT OF THE
 VARIOUS ITEMS IN U.K. REFUSE⁻¹⁰

is a problem to many sewage works because climatic conditions are often not favourable for evaporation.

In England and Wales, the total quantity of dry solids in sewage amounts to some one million tons* annually.⁽³⁾ About half of this ends up on the land while the remainder is disposed of at sea. It is estimated that only 5% of the total is unsuitable for agriculture due to toxic constituents.

Kirkconnel Plant

The Kirkconnel Refuse and Sewage Treatment Plant has operated successfully for four years producing some 550 tons of compost annually. The plant is situated near the village of Kirkconnel in the county of Dumfriesshire, Scotland. Dumfriesshire is an agricultural county of approximately one thousand square miles, and has a population of 45,000 people scattered about in small towns and villages. In the northwest part lies the coal-mining district of Kirkconnel, whose population has recently increased to about 5,000.

History

Before construction of the Kirkconnel Plant, the county engineer Mr. J. C. Wylie experimented in the disposal of sewage sludge and refuse through composting methods.^(4,5) Two projects were started to compost sludge—collected from small drainage schemes—together with vegetable and carbonaceous wastes. The experiment proved successful and a demand was established for the compost produced.

At Kirkconnel, plans for the reorganization of water, drainage, and cleansing services were initiated after World War 2 and a new water source was immediately developed. The expansion of housing development placed the existing refuse disposal and sewage works in an undesirable position. A new site was chosen and in 1950 the Department of Health for Scotland approved the plans for a new works. In May 1953, the Kirkconnel Refuse and Sewage Treatment Plant was officially opened.

Description of the Plant

A diagrammatic layout of the plant is shown in Fig. 2.

Sewage Treatment

The sewage arrives at a measuring flume, passes a storm-separating wier and flows into two primary settling tanks, each of 62,850 gal capacity. Sludge is drawn off from these tanks and the liquid sewage proceeds to two percolating filters each containing 1255 cu yd of filter media and dosed by an 825 gal dosing chamber. The humus tanks (final sedimentation tanks) both have 16,500 gal capacity. The effluent flows into the River Nith and the sludge proceeds to the composting building. About 1,800 gal of sludge at 96% moisture content must be handled daily in the composting process.

Refuse Separation

The refuse arrives in collection vehicles and is dumped into a 35-ton capacity reception hopper shown in Fig. 3. Large objects, such as old bed

*Long tons (2240 lb) are used throughout this paper.

Refuse

population served = 8,000

daily input = 6 tons

annual input = 1839 tons

Sewage

population served = 5,000

dry weather flow = 0.2 mgd^{*}

moisture content of sludge = 96%

Composting

daily accumulation of raw materials

1. 1,800 gal sludge

2. 32 cwt of refuse dust

3. 14½ cwt of vegetable matter

annual compost production = 550 tons

Power Consumption

10 kwhr per day (approximate)

1.64 kwhr per ton of refuse input

Table 2 BASIC DATA OF THE PLANT

* Imperial gallons (1.2 U.S. gal) are used throughout this paper.

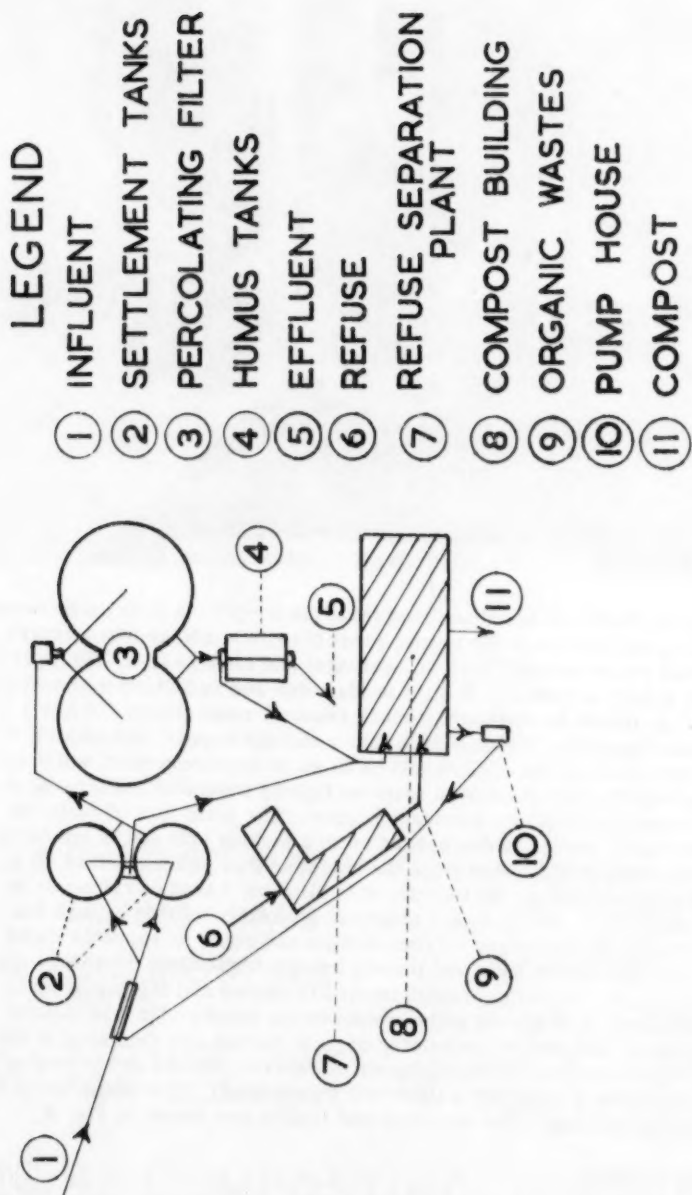


FIG. 2 DIAGRAMMATIC LAYOUT OF WORKS

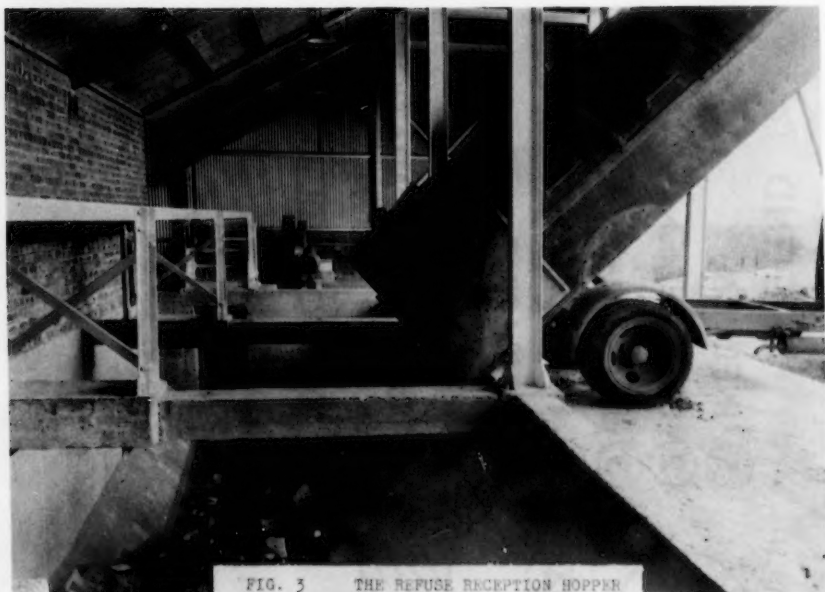
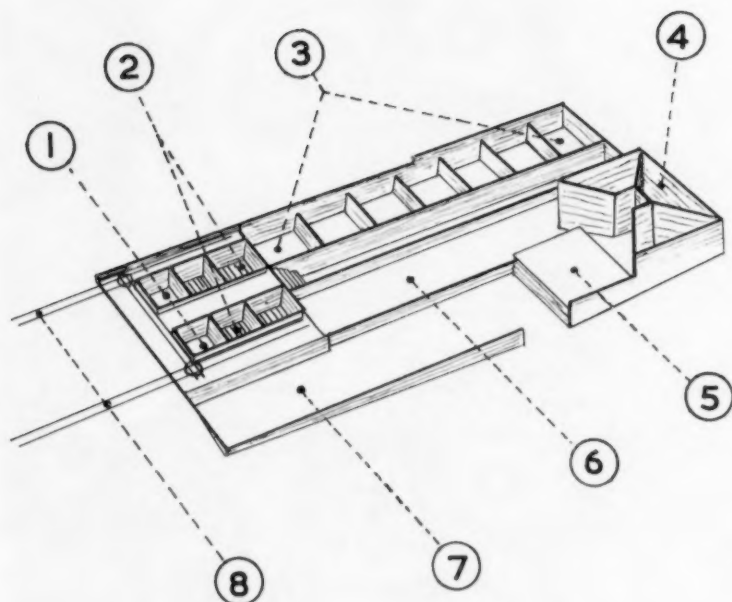


FIG. 5 THE REFUSE RECEPTION HOPPER

springs and so forth are hand removed from the hopper. A drag-link conveyor running along the bottom of the hopper feeds the crude refuse into a rotary screen which removes dust (7/16 in. openings) and cinders (1-1/2 in. openings). The rotary screen is 8 ft 7 in. in diameter and is divided into sections 8 ft and 4 ft in length for dust and cinders removal respectively. It has a 5-ton-per-hour capacity. The dust falls into a storage hopper immediately below the rotary screen; the cinders fall on to an inclined conveyor, which by moving against the flow of cinders extracts lighter vegetable matter and allows the cinders to drop into a storage hopper. The main flow of material leaving the rotary screen is discharged on to a picking belt and is joined by the vegetable matter separated from the cinders. The picking belt is 42 in. wide, 18 ft long and travels at 4-ft-per-min allowing 2 tons of refuse to be dealt with each hour. An overband magnetic separator moving across the picking belt lifts off the larger ferrous metals and other salvageable items are picked off the belt by hand and thrown into chutes leading to storage space on the floor below. Here the various items are sorted and the paper and metals are baled. A magnetic pulley removes the smaller ferrous metals from the picking belt and the remaining organic wastes are delivered to the shredder. The shredder, a flail-hammer pulverizer, breaks up the wastes into fragments which drop into a light-rail wagon ready for transportation to the composting building. The shredder and trolley are shown in Fig. 5.

Composting Building

The composting building is constructed of asbestos sheeting over a steel frame and measures 135 ft by 52 ft. A sketch of the interior of the building showing the arrangements for composting is given in Fig. 4. Fig. 6 is an



① DUST STORAGE

② MIXING BAYS

③ COMPOSTING
BAYS

④ STORAGE BINS
FOR COMPOST

⑤ LOADING
PLATFORM

⑥ MATURING BAY

⑦ STRAW STORAGE

⑧ RAILS FOR
TROLLEY

FIG. 4 COMPOSTING BUILDING



FIG. 5 THE SHREDDER DROPPING PULVERIZED WASTES INTO THE LIGHT-RAIL WAGON

interior view of the building. Storage space is provided for 200 cu yd of waste vegetation, 30 cu yd of refuse dust, and 130 cu yd of finished compost. Three mixing bays and a storage bay for shredded refuse, each of about 18 cu yd capacity are provided. The walls of the mixing bays are constructed of brick and the floors have been designed to allow any excess liquid to collect in a central drainage channel running the whole length of the building. The composting cells measure 14 by 13 ft and are 5-1/2 ft deep. They are of similar construction to the mixing bays but the side walls each contain 12 ventilating holes which facilitate the circulation of air in the fermenting material. A large maturing bay is provided together with space for chopping, screening and bagging the finished compost. A three-way travelling grab of 20 cu ft capacity handles the moving of materials within the building. The grab can be seen on the right-hand side of Fig. 6.

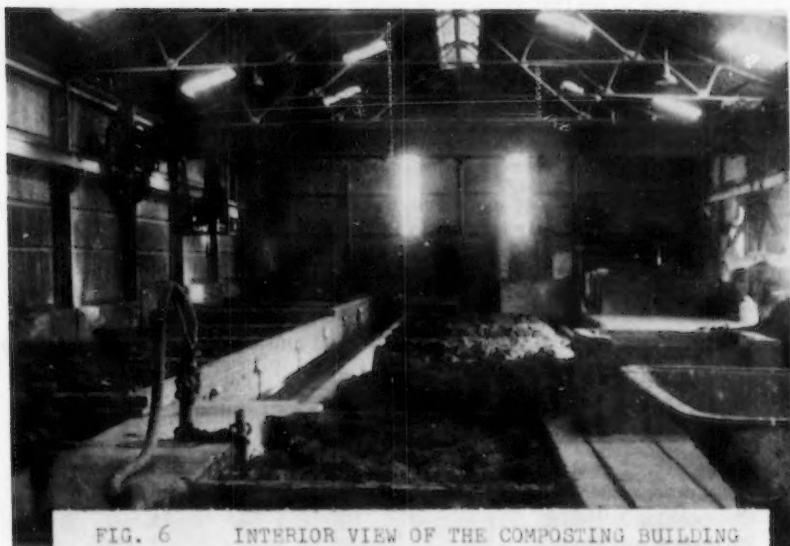


FIG. 6 INTERIOR VIEW OF THE COMPOSTING BUILDING

Composting Process

The wastes are mixed together in the proportions of 1,000 gal of liquid sludge to about 18 cwt of dust and 8 cwt of vegetable matter.⁽⁴⁾ Thus the daily accumulation of some 1,800 gal of sludge requires about 32 cwt of dust and 14-1/2 cwt of vegetable matter to form the raw compost mixture. Straw is used to augment the supply of vegetable matter; it helps to improve the texture of the raw compost by providing a better filtration effect when the sewage sludge is applied, and also it keeps the heaps loose and consequently aerobic.

A 9-in. layer of refuse dust and shredded vegetable wastes is first laid on the floor of a mixing bay. 600 gal of sludge are applied to this layer through a flexible hose. The excess moisture filters through the bed of material, collects in the under-drainage system, and is pumped back to the inlet of the sedimentation tanks. The remaining mixture is mixed with forks breaking up the surface skin and both aeration and filtration action are increased. 20 lb of ground limestone are sprinkled over the layer. This process of laying 9-in. layers and then applying sludge continues till the mixing bay is full.

Once each week the raw compost from the mixing bays is moved into a composting cell by the travelling grab where it is built into a loose heap through which vertical holes are punched to facilitate aeration. It remains for about five or six weeks in the composting cell.

Aerobic fermentation begins in the mixing bays and reaches a peak after the material is turned into the composting cells. The approximate temperatures reached are 135° F in the mixing bay, 180° F peak during the first week in the composting cells, falling off to about 125° F during the last week in the composting cells. The compost is then moved to the maturing bay where biological activity decreases.

The finished compost is sold in bulk to farmers, or chopped and screened and sold in bags to market gardeners and private gardeners. The compost is sold under the name "Eradite" at the following prices ex works:

1 - 10 cwt	7/6 (\$1.05) per cwt
10 - 20 cwt	6/- (\$0.85) per cwt
1 - 5 tons	100/- (\$14) per ton
5 - 10 tons	90/- (\$12) per ton
10 tons and over	80/- (\$11) per ton

The variation in limits of moisture, oven-dry matter, nitrogen, phosphoric acid, potash and carbon/nitrogen ratio in the compost are given in Table 3. In Table 4, the trace element content of a sample of compost is given.

Economics⁽⁹⁾

The capital cost, annual operating costs, and annual revenues are given in detail below.

Capital Cost (1953)

	£*
Sewage treatment works	31,500
Refuse separation plant	18,500
Composting building	11,500
Workshop and garage	2,500
	<u>64,000</u>

Annual Operating Costs

Sewage Treatment	
Labour	250
Power	5
Supplies, etc.	64
	<u>319</u>
Separation and Salvage	
Labour	1,552
Power	30
Supplies, etc.	127
	<u>1,709</u>
Composting	
Labour	776
Power	80
Supplies, etc.	332
	<u>1,188</u>

Annual Revenues

Separation and Salvage	
Baled tins	285
Paper	544
Scrap iron	39
Rags	270
	<u>1,138</u>
Composting	
Compost sales	1,531

*One Pound sterling = \$2.80 during the period 1952 - 57.

Moisture	Oven Dry Matter		Nitrogen, Phosphoric Acid and Potash as Percentage of Dry Matter		Carbon/ Nitrogen Ratio
	Mineral	Organic	N	P ₂ O ₅ : K ₂ O	
40 - 45	50 - 55	45 - 50	1.0-1.3	0.5-0.6	0.3-0.35
					15-20/1

Table 3 VARIATION LIMITS OF KIRKCONNEL COMPOST⁶

Amounts Soluble in Dilute (2.5 per cent.) Acetic Acid After Ignition Expressed as Parts Per Million Oven Dry Matter	
Co. : Ni.	Mo. : Fe. : Pb. : Sn. : Zn. : V. : Ti. : Cr. : Ag. : Mn. : Cu.
1.7 : 4.3	1.7 : 50 : 18 : 1 : 130 : 4.8 : 0.4 : 0.7 : 0.1 : 22 : 28

Table 4 TRACE ELEMENT CONTENT IN KIRKCONNEL COMPOST⁶

Summary

Thus, Separation and Salvage has a net operating cost of £571 per annum; Composting shows a net profit of £343 per annum.

The net cost of refuse disposal is £228 per year, or 2s. 5-3/4d. (35¢) per ton of refuse input.

The overall cost of operating the plant amounts to £ 547 per year.

Remarks

Method

The method of composting employed is basically the Indore system with the modifications of proper drainage and more frequent turning. It is not the most rapid or highly mechanised method of composting in use today, but for a plant of this size it has proven most satisfactory.

Equipment

The equipment installed has operated efficiently except for two minor exceptions. The secondary cinders—garbage separator has given some trouble and its performance is not 100% effective. The hammers in the shredder had a high rate of wear and it was found that by removing every second hammer, the wear was decreased along with the maximum partical size of the product. It is also easier to feed the refuse into the machine with the new arrangement of hammers.

Economics

In the section on economics, depreciation and capital repayment have been excluded. These two items increase the annual operating costs considerably; however, the definite savings in land area with no sludge drying beds needed, the tidiness of operations, the lack of air and ground water pollution, and the returning of humus to the soil where it will be of most immediate benefit are all factors which help to balance the economic picture.

Product

The product is most satisfactory and is supplied to a wide variety of growers in the area. The present trend is to increase the sales in cwt bags. This has come about because a few bulk sales to local farmers can account for the whole output of the plant, and thus seasonal changes in their farming methods could gravely affect the tonnages sold from year to year. By increasing the sale in bags to a wider variety of growers, the market for compost is kept more uniform providing a steady income for the plant.

Working Conditions

An important feature of the plant is the improvement in working conditions. The workmen in general have taken an interest in the process which is creative when compared to the usual refuse disposal practice and this is encouraging. A sincere interest has been taken in the plant by all those connected with it. Mr. Wylie's hard work in the creation of the plant was responsible for its success in the early stages. Mr. Fletcher, the present Dumfries County

Engineer, and his staff have taken a keen interest in the plant and are continually improving it. The plant is kept tidy and in good working order and the credit for this falls mainly upon the foreman in charge who has developed a sincere interest in the process.

The Kirkconnel Refuse and Sewage Treatment Plant provides the service for which it was designed; both refuse and sewage are disposed through composting. Compost sales have proved successful and the demand for the product appears to be continually increasing.

Jersey Plant

The Bellozanne Valley Refuse and Sewage Treatment Plant is situated in Jersey, the largest of the British Channel Islands. Jersey is 45 square miles in area and lies in the English Channel about 20 miles west off the Cherbourg Peninsula. The island has a resident population of 57,000 which increases to over 90,000 in the summer. The principal industries are market gardening (truck gardening) and tourism; potatoes, tomatoes and flowers are exported to England, while some 100,000 English visitors spend their vacation in Jersey each summer.

History

The States of Jersey decided to review the whole problem of sewerage after World War II and Mr. S. A. Gothard was appointed as Consultant Engineer to the States of Jersey in 1948.

The following problems existed in Jersey at that time:

1. The sewer system in St. Helier (the capital and only city) was over 100 years old and needed replacing.
2. The concentration of septic tanks in parts of the Island was too great and ground water supplies were in danger of being polluted.
3. Beach pollution due to sewage was becoming a problem.
4. The useful life of an incinerator plant was over and space for tipping was not available.
5. Soil fertility was on the decline in spite of the large quantities of artificial fertilisers and seaweed used by the local growers.

Two different systems were investigated. Firstly, a new sewerage system discharging directly into the sea from an outfall sewer, and secondly, a new sewerage system bringing the sewage to a site for treatment. From a survey of tidal currents, it was found that crude sewage discharged into the sea would always pollute some beaches, no matter where the point of discharge. This ruled out the first method and the second was developed. The ideal solution satisfying all the requirements, including the lack of space available, was a compact disposal method which could deal with all wastes and produce a cheap fertilizer. Composting was a possible solution.

The Pilot Plant

No proprietary type of composting plant was available which satisfied all the local circumstances. A new system was developed under Mr. Gothard's direction and tested for over four years in a pilot plant. The pilot plant is shown in Fig. 7, and consisted of a tower with 6 floor levels, each level

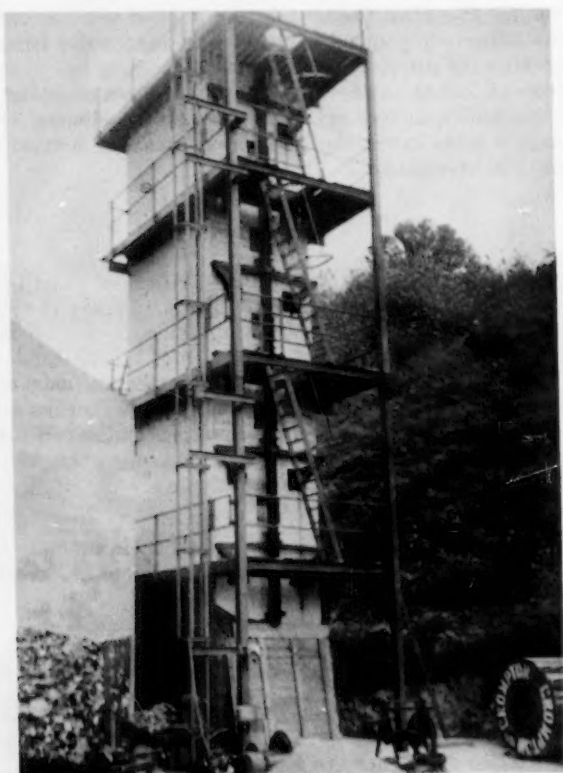


FIG. 7 PILOT COMPOSTING PLANT

containing a batch of fermenting compost. The raw compost was introduced into the top floor of the tower where it remained for one day. The fermenting material was dropped one floor level each day. After six days fermentation in the tower cells, the material was removed to maturing piles where it remained a further six weeks to stabilize.

The four years of trials with the pilot plant achieved the following:

1. The cell units on the tower principle proved efficient and a roll-over-unit was developed for use in the main plant.
2. The various proportions of shredded garbage, sewage sludge, and refuse dust which could be composted satisfactorily were found.
3. The compost produced by the pilot plant was tested by agricultural authorities and local growers. Its value was established and a market for it developed.

The Main Plant

The results of the trials with the pilot plant enabled Mr. Gothard and his staff to gain experience of composting the wastes in Jersey, and the work of designing the main plant was greatly facilitated.

One of the most difficult problems encountered was how to absorb all the sewage sludge in the organic garbage available, and at the same time keep the moisture content of the raw compost mixture low enough for aerobic fermentation. Sludge drying beds were not possible due to the restricted site area, and it was decided to use super thickening of the sludge after digestion. It is anticipated that the sludge produced will have a low enough moisture content so that all of it can be incorporated in the raw compost mixture.

Fermentation Cells

The most important and interesting part of the Jersey plant is the composting section. The fermentation cells developed from the pilot plant have proven satisfactory.

The principle of this system is simply fermentation in cells with intermittent disturbance providing aeration. The method of operating the fermentation cells is shown in Fig. 8. In Sketch A, the bottom floor-trough-units have discharged compost into a trailer ready for removal to the maturing building. In Sketch B, the second floor trough-units have discharged compost into the bottom floor trough-units. Each batch of compost is dropped one floor

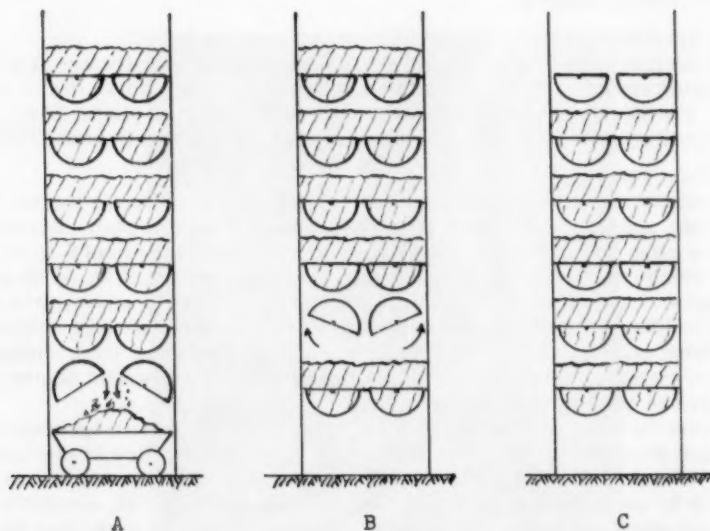


FIG. 8 METHOD OF OPERATION OF FERMENTATION TROUGH UNITS.

till as in Sketch C, the top floor is ready to receive a day's input of raw compost. Fig. 9 is an interior view looking along the fifth floor, and Fig. 10 shows the fourth floor trough-units before the upper floor troughs had been installed. The raw compost mixture is placed into semi-cylindrical trough units which have stub axles fitted to their end plates. The trough units measure 4 feet in diameter and are 10 feet long. The composting material is heaped to about 2 feet over the rims, and holes have been made in the troughs to help aeration. The material remains fermenting for one day in the top floor and then is dropped one floor into similar trough units where it remains for a further 24 hours before being dropped to the next floor. The trough units rotate inwards in pairs through 360° and turn the fermenting material over each time it is dropped. The peak of aerobic decomposition occurs on the 3rd, 4th and 5th floors where the temperature is constantly in the 140° to 160° range. Thus, after six days in the fermentation cells, all material has been subjected to temperatures lethal to pathogenic organisms and the material is unattractive to flies when it emerges from the fermentation cells. Further stabilisation is achieved during a six to eight week period in maturing piles which also serves as storage to meet fluctuations in market demands.

The main plant came into operation in April, 1957.

Description of the Plant

A diagrammatic layout of the Jersey plant is shown in Fig. 11 and basic data are given in Table 5.

Sewage Treatment

This section of the works is still under construction. The treatment will be activated sludge with sludge digestion followed by super-thickening of the sludge. The thickened sludge will be pumped to the compost plant. The sewage treatment section will be working in May, 1959, and will cost £350,000.

Refuse Separation

The refuse is dumped from collection vehicles into a reception hopper of 100 cu. yds. capacity from which it is withdrawn by a moving plate conveyor into the sorting building. The refuse is fed into a rotary screen of 6 ft. diameter which has 3/8 in. openings for dust removed, and 1-1/2 in. openings for cinders. The screen is 18 ft. long. The dust proceeds by conveyor to a storage building of 1,000 cu. yds. capacity where it is automatically weighed before being placed into storage. An overhead grab feeds dust from storage into the reclaiming system which automatically records the weight before the dust is moved away by belt conveyor.

The cinders which are extracted through the 1-1/2 in. screen openings are discharged directly into vehicles standing below. The main flow of material passing through the screen arrives at the picking belt. The picking belt is 59 ft. long, 3 ft. wide and moves at 40 ft. per minute. Glass, cullet, non-ferrous metals and other non-compostable materials are removed by hand from the picking belt and thrown into chutes which lead to the floor below, where metal baling and further separation are carried out. An overband magnetic separator removes ferrous metals from the picking belt and drops them to the baling press on the floor below.

The material remaining on the picking belt is passed into a Rasp type pulveriser. The Rasp is a Dutch machine designed specifically for shredding town refuse. The incoming refuse drops on to radially sweeping arms which

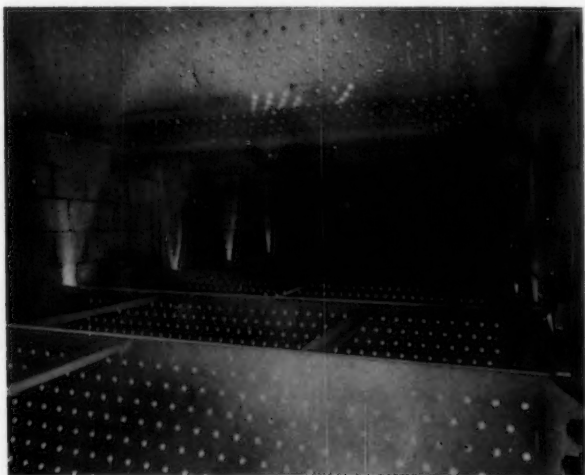


FIG. 9 INTERIOR VIEW OF COMPOST CELL UNITS



FIG. 10 INTERIOR VIEW OF COMPOSTING BAY

REFUSE

Population served = 57,000 + 37,000 in
visitor season

Daily input = 60 tons

Annual input = 14,000 tons

SEWAGE

Population served = 50,000

Dry weather flow = 3.3 mgd (estimated)

Moisture content

of sludge = 90% (estimated)

COMPOSTING

Average daily quantities of raw materials
introduced into the compost mixture are:-

1. 28 tons sludge
2. $6\frac{1}{2}$ tons refuse dust
3. 25 tons pulverised products

Annual compost production = 10,000 tons
(estimated)

POWER CONSUMPTION

7-10 kwhr per ton of refuse input

Table 5 BASIC DATA OF THE PLANT

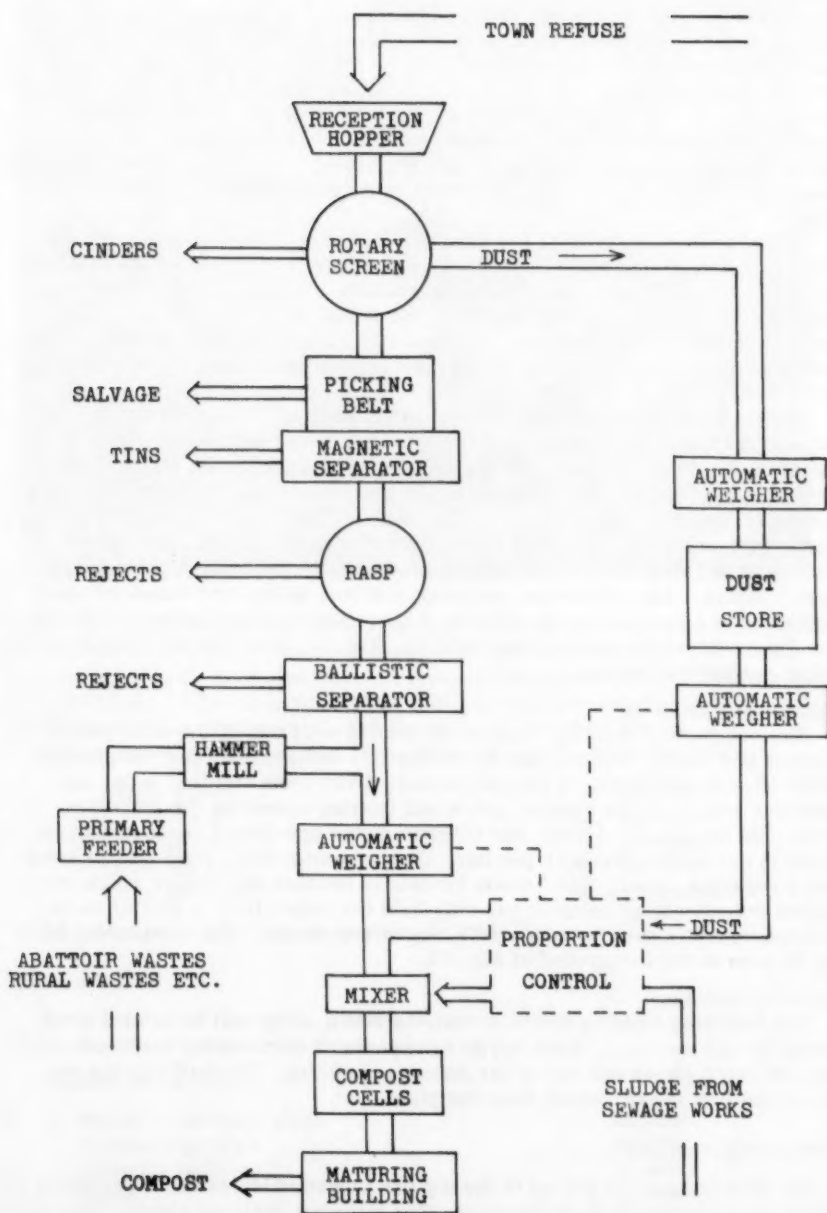


FIG. 11

FLOW DIAGRAM OF THE JERSEY COMPOSTING PLANT

rotate in a horizontal plane. These arms move the refuse over steel plates which are alternatively holed and pegged. The refuse is torn and shredded by the pegs and drops through the holes on to a collecting deck below. At intervals, the flow of incoming refuse is stopped and the arms are kept rotating till only material which will not pass through the holes is left turning with the arms. A side door is opened and this material is rejected. The door is closed and the Rasp is ready to receive the flow of incoming refuse. The material passing through the holes (1-3/8 in. diameter) is collected on a circular deck below. The Rasp is approximately 18 ft. in diameter and stands 17 ft. high.

The shredded material is fed from the Rasp into a beater-type ballistic separator which separates the lighter organic matter from inorganic material, such as broken glass, nails and other items. This is accomplished by giving all the incoming shredded refuse a horizontal velocity, and the lighter organic material falls out first. The inorganic items generally travel further and fall into a rejects hopper. The product from the ballistic separator is collected and fed on to a belt conveyor.

At this point in the process, wastes which need not be passed through the separation plant are introduced. These wastes have been pulverised by a swing hammermill and they join up with the product from the ballistic separator. The conveyor belt transporting both waste materials passes over an automatic weigher which controls the amount of dust being returned from the dust store, and also the rate at which sludge is introduced into the mixer. The returning dust also is fed onto the main conveyor which in turn feeds a rotary mixer. The pulverised material, dust and sludge are mixed and then deposited in a pit ready to be lifted by a travelling grab and deposited in the top floor cells of the composting building. Fig. 13 shows the top floor fermentation cells being loaded.

Composting Building

The composting building consists of six floors of roll-over-units with 24 troughs per floor. The building is divided into 4 bays, each bay containing 3 pairs of units per floor. A central passage divides the building in two and provides access to the motors, gears and bearing operating the roll-over-units. On the top five floors, one electric motor operates 6 troughs, that is, there is one motor per floor per bay. On the bottom floor, each pair of units has a separate motor. The reason for this is because the trailer which receives the outgoing compost can only hold the output from a pair of units, and consequently each pair has to be turned separately. The composting building is seen in the foreground of Fig. 12.

Maturing Building

The maturing building is 114 ft. wide by 300 ft. long, and is divided longitudinally into two bays. Each bay is equipped with a travelling grab seen in Fig. 14 which shows one bay of the maturing building. The building can accommodate 20 weeks' output from the plant.

Composting Process

The raw compost is placed in the top floor units which can hold one day's output of raw compost from the plant. The material heats up rapidly once in the fermentation cells. Fermentation reaches a peak on the fourth and fifth floors where the temperature is constantly in the range of 140° - 160° F.

FIG. 12 COMPOSTING BUILDING



After six days in the compost cells, aerobic decomposition is well established and the material is removed by trailer to the maturing building. The material is piled up to 6 foot heaps where it remains decomposing for a further six to eight weeks. After this period the C/N ratio is down to around 15/1, and the pH value very near neutral, and the compost is ready for use.

The compost is sold directly from the works at the following prices:

Under 1 ton	5/- per cwt.
1 - 10 tons	40/- per ton.
Over 10 tons	35/- per ton.
Over 100 tons	30/- per ton.
Over 200 tons	By arrangement.

An analysis of the compost is given in Table 6.

Economics⁽¹¹⁾

Both the Annual Operating Costs and Annual Revenues are estimates because the plant has not been running for a whole year.

Capital Costs (1956)

Refuse separation plant	80,000
Composting cells	60,000
Maturing building	43,000
Other	39,000
	<u>£222,000</u>

FIG. 13 TOP FLOOR FERMENTATION CELLS BEING LOADED



Annual Operating Costs (estimated)

Labour	17,200
Power	1,400
Supplies and Miscellaneous	<u>9,600</u>
	£28,200

Annual Revenues (estimated)

Tins	4,500
Scrap Iron	350
Rags	<u>200</u>
	£5,050

Compost Sales

No estimate has been given for the annual revenue from compost sales. However, up to December, 1957, 3,000 tons of compost had been sold at an average price of 33 shillings per ton, giving a revenue of £4,950 for the first six months of operation.

Remarks

Method

The plant in Jersey is an example of composting in cells on the intermittent disturbance principle. The trough units in the fermentation cells have proved effective and the temperatures developed in the cells are high. There does not appear to be any tendency for anaerobic conditions to set in. The total



FIG. 14 MATURING BUILDING

time of the process is seven to nine weeks which is fairly long, but this retention period at the plant could be cut considerably if the final maturing was done in heaps on farm land.

Equipment

The mechanical equipment has proved satisfactory with the exception of the hammermill. As was the case at the Kirkconnel plant, the hammermill gave excessive wear and not a uniform product. The hammermill was replaced by the Rasp shredder and the original mill is now kept as a standby machine.

Economics

It is unfortunate that the plant has not been in full operation for a whole year with the complete costs and revenues available. The indications are that the total operating cost will be lower than was estimated. A rough check made in the spring of 1958 gave the cost at approximately £23,000 against the £28,200 estimate. The total income from salvage and compost will be about £15,000 annually giving a net cost of refuse disposal of £8,000 per year, or 11-1/2 shillings per ton of refuse input. The cost of refuse disposal in 1956 by incineration was £25,000. These figures may be improved when the full sludge load comes into the plant in May 1959, because the output of compost will be increased along with the quality. The operating costs may also be reduced in the second year of operations when most of the teething troubles will have been eliminated.

No. of Sample	41	K ₂ O	0.20
Extraneous Matter % W/W on sample as received	3.2	CaO	1.54
Moisture	42.4	MgO	0.18
Mineral Matter	40.0	Na ₂ O	0.32
Loss on ignition	17.6	Copper	0.018
Organic Matter (Organic Carbon x 1.724)	13.4	Boron	0.008
Organic Carbon (Walkley & Black)	7.77	Molybdenum	0.0001
Nitrogen	0.52	Zinc	0.084
C/N Ratio	15.0	Manganese	0.050
P ₂ O ₅	0.43	Cobalt	0.002
		Iron as Fe ₂ O ₃	0.91

Note: All figures with the exception of "Extraneous Matter" and Ratios are expressed in % W/W of sample remaining after removal of extraneous matter.

February, 1958

Table 6

ANALYSIS OF JERSEY COMPOST

Product

The product has undergone extensive tests at the States Agricultural Station, and it has been found that:

1. The compost will not taint crops grown in it;
2. The compost contains a useful amount of plant food as well as humus forming material; and
3. The compost is inoffensive, easy to handle and can be used at any time of the year.

The type of agriculture in Jersey is intensive cropping on a small scale which is most suitable for the use of organic fertilizers such as compost and farmyard manure. Today, little farmyard manure is available and the compost from the refuse disposal plant will help to keep soil fertility at a high level. The attraction of clean beaches to tourists coupled with a high soil fertility are vital points in the island's economy; the compost plant is aiding both aspects.

The planning, design, construction and running of the plant is under the control of Mr. S. A. Gothard and his staff who must be congratulated for their ability in producing this scheme. Utilization appears to be a sound solution to the problem of waste disposal in Jersey.

Other Composting Plants in the U. K.

Leatherhead

The first serious attempt at municipal composting started at Leatherhead in 1936 under the direction of Mr. J. L. Davies, the Borough Engineer, and the plant is still in operation. Refuse is sorted and the compostable portion is pulverised and then mixed with sewage sludge in shallow lagoons. The raw compost is left for about three days and then transferred by mobile shovel to heaps where it continues to ferment for a further ten days. The material is moved to maturing heaps where it remains till sold.

About 1,000 tons of refuse are composted annually with some 2,000 tons of sludge at 97% moisture content producing 1,800 tons of compost at over 60% moisture content. The compost is sold at an average price of £1. per ton to local growers.

The Leatherhead plant has been badly overloaded for the past ten years, and attempts to obtain a loan to replace the plant have just recently been successful. The plant made a contribution to composting during the first years of operation, but during the latter years it has hindered the advancement of composting. Visitors seeing Leatherhead as their first composting experience tend to leave with a bad impression due to the poor conditions at the plant. The new plant will come into operation within the next year or so.

Edinburgh

The City of Edinburgh installed a Dano composting plant for experimental use at Seafield in July, 1955. The plant is under the direction of Mr. N. G. Wilson, Engineer and Manager of the Lighting and Cleansing Department.

The Dano plant consists of a large horizontally rotating cylinder with closed ends which is kept continually turning. Material to be composted is introduced into the cylinder at one end at a steady rate, and the composted wastes are extracted at the other end after approximately five days of turning inside the cylinder.

The plant was tested on handling crude refuse; 20 tons of crude refuse were put into the plant per day (ferrous metals having been extracted from the refuse) with 150 gallons of sewage sludge per ton of refuse and 14 tons of composted material, together with 6 tons of reject material were produced. The plant was tested also on "tailings", the portion of refuse which is burnt in the incineration process. Difficulties were experienced in introducing this more bulky material into the cylinder and the breakdown inside the cylinder was slower. A new inlet was designed and cutting edges were inserted at the inlet end of the cylinder. With these modifications, the Dano plant successfully handled "tailings".

The retention period in the Dano plant is 5 days or more. During this time the material is mixed, broken down physically and biologically decomposed. The temperatures developed are in the range of 115° to 130° F. Air is injected into the cylinder under low pressure. The material produced in 5 or 6 days has a C/N ratio generally in the range of 30 to 40 which is too high for immediate use on land where crops are growing. When the compost is stockpiled for several weeks, the C/N ratio is lowered considerably. The compost was originally sold for £2. per ton ex works.

Craigmillar Plant

A new Dano plant will shortly be in operation in Edinburgh. This plant will receive 140 tons of crude refuse per day; the refuse will be passed through a separation plant where dust, cinders, metals and other salvageable items are extracted; two Dano cylinders with a total input capacity of 70 tons per day will compost the remaining portion of the refuse and the refuse will be retained in the cylinders for approximately five days. The product from the cylinders will be screened to remove extraneous material.

The compost from all the Dano plants in Edinburgh will be sold by a separate organisation which has contracted to buy all the compost from the Edinburgh Corporation and market it.

General Trend in Composting

Many municipal authorities in the United Kingdom are interested in the possibility of refuse and sludge disposal through composting. Due to caution and the present "credit squeeze" policy of the Government, these authorities are not venturing into composting at the present moment. However, depending upon the results from Jersey, Edinburgh and others who are composting, a serious intention has been expressed to go ahead with composting in the near future.

ACKNOWLEDGMENTS

The detailed information presented in this paper is mainly due to the kind cooperation of the following people:

Mr. L. P. Brunt, Chief Engineer, Compost Engineers Ltd., London, whose advice was extremely helpful;

Mr. J. W. Fletcher, County Engineer, Dumfries, Scotland, who supplied detailed information about the Kirkconnel plant;

Mr. S. A. Gothard, Consulting Engineer, Jersey, Channel Islands, who supplied detailed information about the Jersey plant and photographs; and

Mr. J. C. Wylie, Consulting Engineer, Edinburgh, Scotland, who supplied photographs of the Kirkconnel plant and other information.

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Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

SED RESEARCH REPORT NO. 21

On	SANITARY LAND FILL TESTS INVESTIGATING REFUSE VOLUME REDUCTION AND OTHER PHE- NOMENA
By	The Sanitary Engineering Research Committee, Solid Waste Engineering Section
From Research Data of	Walter L. Dunn, Assistant Professor, General Engineering Department University of Washington, Seattle, Washington
Acknowledgement	The Sanitary Engineering Division gratefully recognizes the generosity and professional courtesy of Professor Dunn in making available information for this review.

SYNOPSIS

At the Union Bay Sanitary Landfill Disposal site, Seattle, Washington, tests have been performed over a one year period to ascertain compaction, settlement, fill temperature and gas production. These data are critically reviewed with reference to obtaining optimum refuse disposal volume into a given landfill area.

INTRODUCTION

The sanitary landfill is probably the most economical and widely accepted method for disposing municipal solid wastes. A sanitary landfill often utilizes valuable and limited areas of land for the ultimate storage and disposal of refuse. Methods of improving initial and ultimate refuse volume reduction

Note: Discussion open until April 1, 1959. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 1853 is part of the copyrighted Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 84, No. SA 6, November, 1958.

serve to increase the life of a sanitary land fill and hence promote economical and long term operations. Tests have been completed at the Union Bay Sanitary Landfill Disposal, seventy-acre site at Seattle, Washington, for a one year period, July 1955 - June 1956. This site is located in what was originally a swamp land underlain with peat type soil extending down to maximum depth of some 60 to 70 feet below the bottom of the landfill.

Some 10,500 cubic yards of refuse including garbage was disposed of from July 11 to July 15, 1955 into a test fill control area. About 10% of this refuse was delivered in packer type equipment trucks. After spreading, the refuse was compacted, by means of a heavy tractor, into about 1 foot depth layers; these layers of refuse were built up into 8 feet cells including a 1 foot depth imported earth cover layer. The test fill had a final total depth of some 20 feet and was some 125 feet long by 36 feet wide. After compaction by the tractor, the original imported earth cover volume was reduced to 615 cubic yards, about 60% of the original trucked earth volume. These tests indicated that the refuse as a result of initial in place compaction was reduced to a volume of 3,300 cubic yards or about 31% of the original delivered volume. The reported ratio of original imported loose earth cover to the compacted in place refuse was about 1 to 3.

Settlement

After one year the 20 foot depth test fill settled an additional 4 feet. On a loose volume basis the refuse delivered in the collection trucks was then reduced to 2,600 yards or 25% of its original volume. Most of this settlement occurred during the first 60 days following placement in the landfill. The remainder of the year showed only minor additional settlement.

Settlement under the test fill was determined by means of an extendable length 2" diameter steel pipe welded to a square steel base plate (3' x 3' x 3/8") located at the bottom of the sanitary fill.

Temperatures

Temperatures within the test fill were recorded during the year by lowering a thermometer into the 2" diameter pipe and taking readings at various depths. The maximum temperatures for the entire year were generally about 15° F greater than the average daily air temperatures.

Gas Productions

Relatively large quantities of combustible methane gas and some carbon dioxide gas were reported to be generated in the fill. Analyses indicated that a fraction of less than 1% other gases were also continuously evolved throughout the test year. Most gas production was observed to occur in the 6 to 24 months in place land fill. Landfill areas receiving additional moisture and containing greater refuse fill depths were reported to have increased gas production.

Critical Evaluation

The Seattle, Washington, Sanitary landfill test data indicates that considerable biological action may occur in a landfill, which can assist in achieving maximum refuse volume reduction. The use of large quantities of soil in a landfill, although possibly desirable for sanitary control, unfortunately reduces the storage volume available for refuse disposal. Optimum uses of scarce land for sanitary fill type refuse disposal would achieve high initial maximum compaction followed by ultimate conversion of most organic solids to gases and liquids accompanied by optimum settlement so that additional refuse could be supplied to the surface of the same site.

CONCLUSIONS

1. Refuse after being placed in a sanitary fill and compacted by a heavy tractor in 1 foot depth strips was reduced in volume to about 31% of the original truck delivered refuse volume.
2. After being placed in the sanitary land fill one year, the total refuse landfill volume was further reduced to approximately 25% of the original truck delivered refuse volume.
3. The most rapid rate of settlement of the landfill occurred during the first 60 days following placement.
4. The sanitary landfill temperatures averaged some 15° F more than the average daily air temperatures throughout the year.
5. Methane gas, carbon dioxide and a fraction of less than 1% of certain noxious gases were evolved. Optimum gas production occurred following addition of water and in the deeper fills after 6 to 24 months in place storage.
6. Efficient sanitary landfill operations would utilize maximum biological degradation of the refuse in order to achieve optimum fill settlement and thereby provide additional refuse volume disposal capacity at the same site.

Credit

This research report, which is one of a series of professional contributions by the Committee on Sanitary Engineering Research,

E. R. Hendrickson)	Air Pollution
W. T. Ingram)	
M. A. Churchill	Stream Pollution
R. W. Bogan	Sewage
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has been prepared by the Solid Wastes Engineering Section

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REPORT OF THE COMMITTEE ON THE REVISION OF THE
AMERICAN MEDICAL ASSOCIATION'S
RESOLUTIONS ON THE
MORALITY OF THE PHYSICIAN
ADOPTED AT THE ANNUAL MEETING OF THE ASSOCIATION
AT ST. LOUIS, MO., DECEMBER 1, 1934

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MORALITY OF THE PHYSICIAN
ADOPTED AT THE ANNUAL MEETING OF THE ASSOCIATION
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EFFECT OF LOCAL WEATHER ON AIR-POLLUTION PROBLEMS^a

Closure by A. L. Danis

A. L. DANIS,¹—Mr. Dias' comments on the writer's paper were welcome because they bring out additional factors which must be considered in the diffusion and/or dispersion of pollutants in the atmosphere.

It is questioned whether a wind tunnel study would permit one to evaluate successfully the complete diffusion capacity of the atmosphere due to the aerodynamic and terrain influences except under the most optimum parameters of the many variable properties of the atmosphere.

In model studies of any realistic situation, the question of dealing with atmospheric convection and complex orographic flow due to differential and variable surface heating is most difficult. There is no doubt that much valuable information can be obtained from the study of a "basic plume".

In the writer's opinion, it is well to have different methods tested simultaneously, if at all possible and economically sound.

a. Proc. Paper 1463, December, 1957, by A. L. Danis.

1. Research Prof., College of Eng. Univ. of Florida, Gainesville, Fla.

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WATER INTAKES IN THE DETROIT RIVER^a

Discussions by Remig A. Papp and Frank P. Coughlan, Jr.

REMIG A. PAPP,¹ M. ASCE.—Thirty-one years have elapsed since George H. Fenkell presented his classic paper: "Water Works Intakes of the Great Lakes Region" before the Buffalo Convention of the American Water Works Association. This paper described among others the history and development of the intakes in the Detroit River. The author has made a valuable contribution in bringing the profession up to date on developments along this major source of water supply.

The relatively mild winters experienced during recent years may lull the intake designer into complacency concerning ice problems. Cyclical reversals, however, will come sooner or later and the icing difficulties experienced at many intakes in the past can be expected to reoccur.

In the numerous preliminary designs and cost estimates made while preparing the report, cold weather problems were considered to be of major importance. A tower type intake, rather than a less expensive submerged crib, was recommended as it would be more accessible for combatting ice and provisions could be made for keeping the ports and racks clear by heating or other means. A lagoon intake, in which a protective ice sheet forms, would have been possible at several downstream locations where water quality was inferior.

As originally proposed, the boat shaped intake tower was of the same width but about one third longer than finally designed to allow about 40% more intake port area and thus assure very low inlet velocities even with all the upper ports closed either deliberately or jammed with ice. In addition, it was proposed to provide a central division wall to allow either the "bow" or "stern" to be taken entirely out of service while maintaining flow through the other half. The proposed structure was somewhat more conservative than that finally designed but the decision to reduce cost of this expensive structure is understandable. It will be many years before concurrent high demands and severe weather test the Wayne County intake to its fullest extent in regard to icing. Heating and other de-icing equipment is developing and improving with time and experience and with sufficient flexibility built into an intake to allow for the installation of such equipment, preventive measures can be taken to keep ahead of problems which are sure to grow as intake rates increase.

a. Proc. Paper 1592, April, 1958, by Eugene A. Hardin.

1. Sr. Engr., Hazen and Sawyer, New York, N. Y.

FRANK P. COUGHLAN, JR.,¹ J. M. ASCE.—After commenting on the investigations prior to locating the Wayne County intake, Mr. Hardin states "So, from the standpoint of water quality, an intake could be placed at any feasible point in the main flow channel between the middle of Grosse Isle and the head of Fighting Island, the location being determined in general by the site adopted for the pumping and purification plant". Actually, as noted below, the location of the water intake was determined primarily by quality considerations. Fortunately the best water quality site was nearest the load center of future water demand.

In February 1955, an investigation was undertaken concerning an expansion of the Wayne County Metropolitan Water Supply System to serve the Wayne County area south and west of Detroit. The report⁽¹⁾ submitted on December 31, 1955, established:

- a. The future water demands and the load center of this demand.
- b. The feasibility of a water supply development in the lower Detroit River.
- c. The best water intake location.
- d. The general location of the pumping and filtration plant and transmission mains.

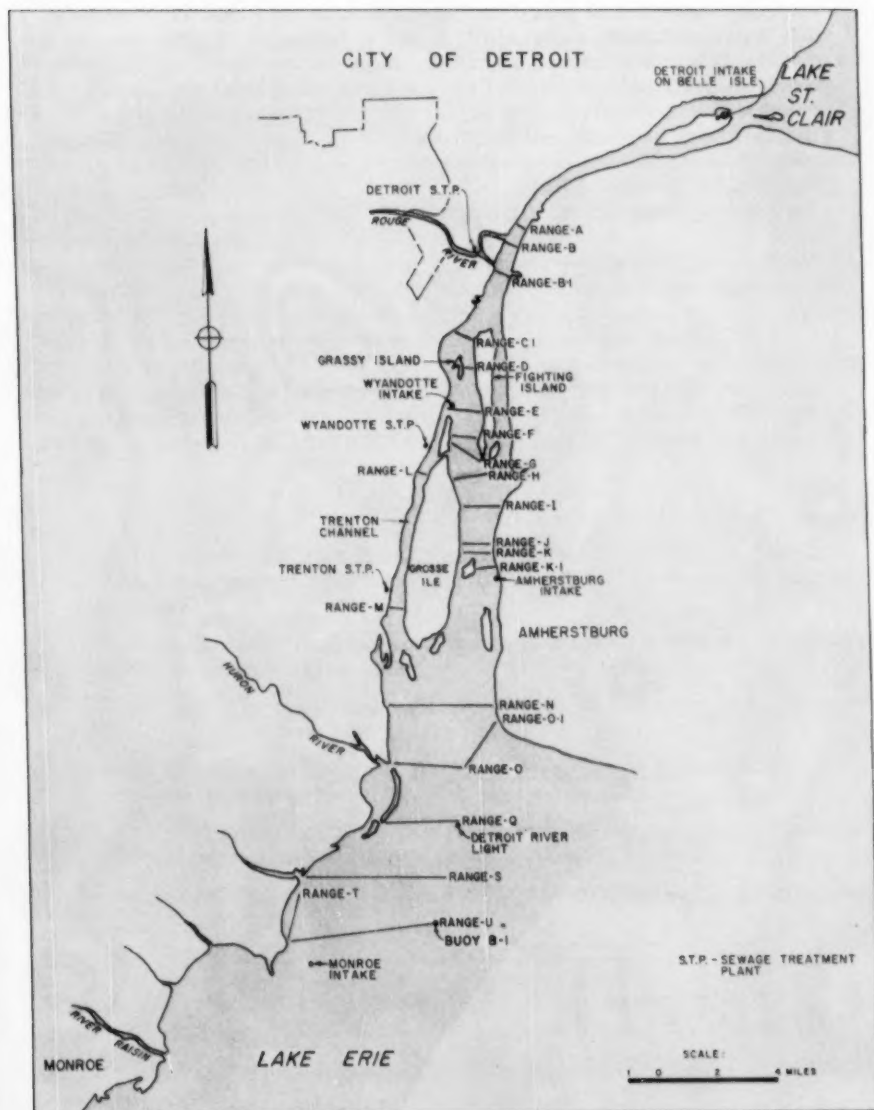
From the start of the investigation it was recognized that the suitability of lower river water for a potable supply hinged upon the natural protection afforded mid-river water by its great flow and by islands, shoals and littoral stratification. Contaminated water is found along both shorelines. If the natural protection were insufficient the intake would have to be positioned in the upper Detroit River or in distant Lake Erie. The disadvantages of a submerged crib in the narrow, navigable, upper river and the taste and odor difficulties of a western Lake Erie supply militated against these secondary choices.

Water quality data had been previously collected by the International Joint Commission^(2,3) in its studies of transfer of pollution across the boundary; and by the Detroit Water Board⁽⁴⁾ in annual checks on the conditions below its sewage treatment plant. These data were valuable in our investigation, but the sampling locations were selected for specific purposes and the frequency of the sampling was limited.

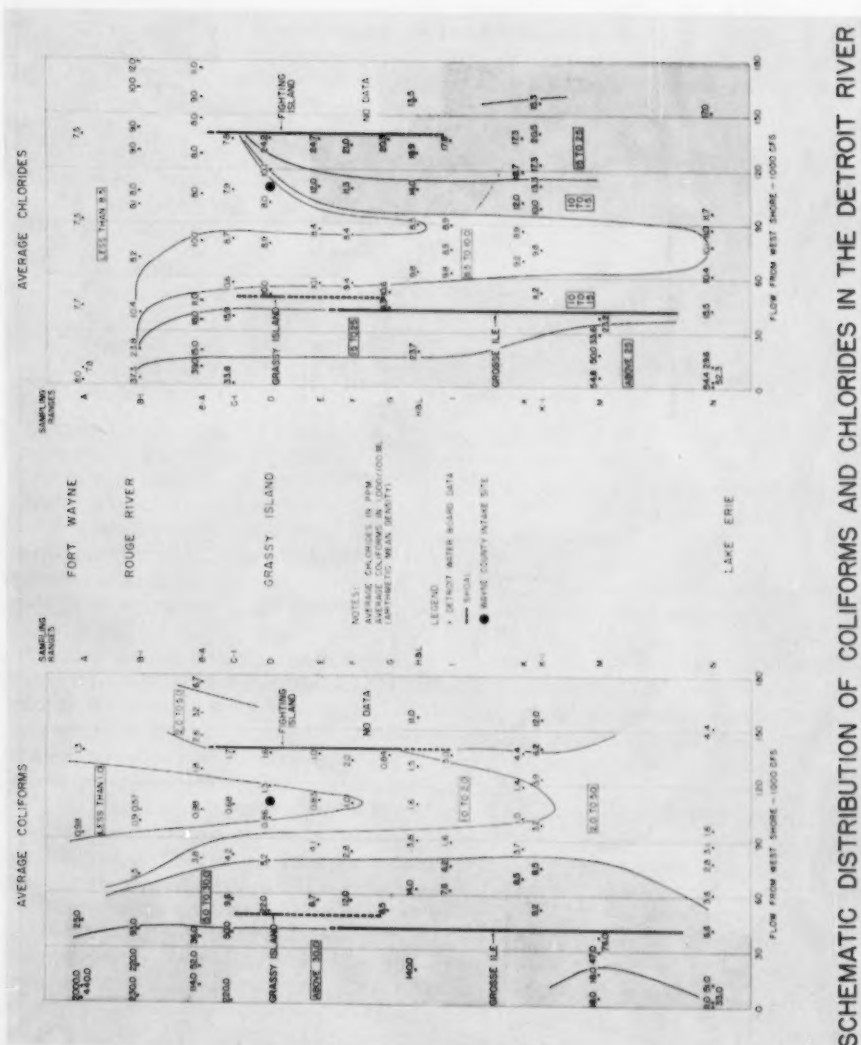
The extent of the survey in the lower river and Lake Erie is indicated in Fig. 1. In all, some 14,000 bacteriological and chemical determinations were performed on 5000 samples taken between April and November 1955. The survey is described in detail elsewhere.⁽⁵⁾

The general results of the survey in the lower river are presented in Fig. 2. Because the quantities of mid-river water unaffected or partially affected by shoreline pollution are not apparent from a true scale map, a schematic representation has been used. The sampling points were located with respect to river flow by hydraulic radius calculations based on U. S. Lake Survey gaging. The Arithmetic Mean Density⁽⁶⁾ method was used to express the "true average" coliform density. Drainage from brine waste beds was responsible for the chloride increase below Fighting Island. The figure indicates that mid-river water is of good quality opposite Grassy Island but that a gradual diffusion of shoreline pollution adversely affects quality at the mouth

1. Hazen and Sawyer, New York 17, N. Y.



SAMPLING RANGES - DETROIT RIVER SURVEY



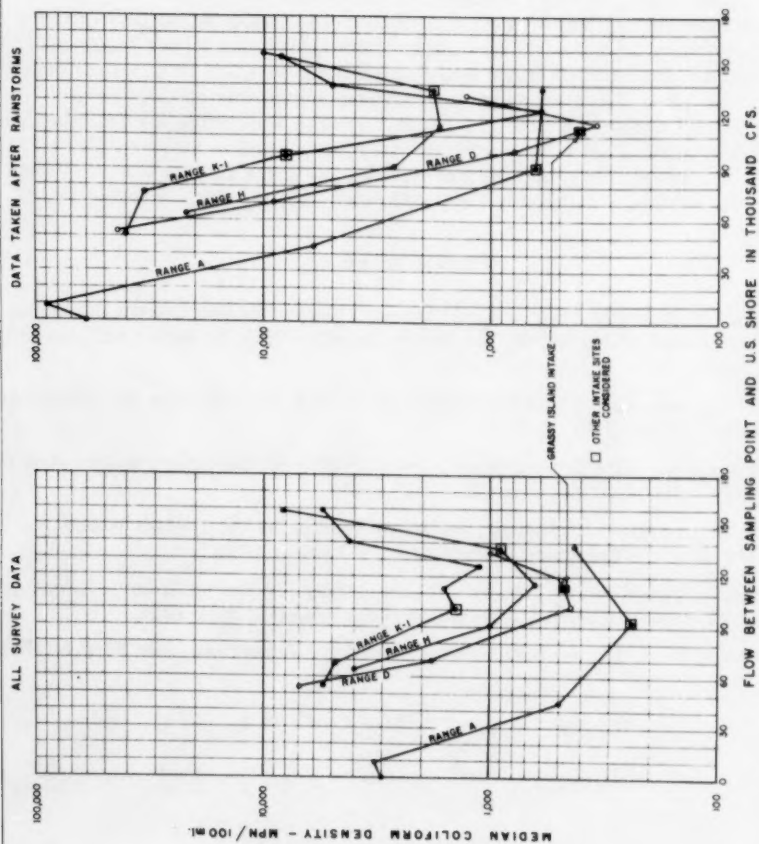
of the river. In general, however, water acceptable in USPHS Class III can be obtained in a 60,000 cfs stream throughout the length of the river.

Further evidence of the superiority of the Grassy Island intake site over downstream sites is presented in Fig. 3. This figure shows the typical coliform conditions found both during the survey in general and particularly after rainstorms. The Detroit sewerage system is of the combined type and there are frequent spills to the river. The quality of mid-river water above the Rouge River (Range A) and opposite Grassy Island (Range D) is only slightly affected by rainstorms. Further downstream at the head of Grosse Ile (Range H) or the middle of Grosse Ile (Range K-1) combined discharges have a greater effect. The vulnerability of the area opposite Grosse Ile to periodic adverse conditions eliminated it from final considerations.

A submerged crib off Fort Wayne and a tower intake off Grassy Island were considered as the best intake sites. The difference in raw water quality is negligible, and filtered water would be entirely safe and of excellent quality from either site. The tower intake off Grassy Island was chosen for the Wayne County intake because (a) a tower intake is accessible for maintenance and repair, while a submerged crib is inaccessible and is more subject to damage from navigation, and (b) a project taking water from a Fort Wayne intake would have cost at least \$ 6,000,000 more than the Grassy Island intake.

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2. International Joint Commission survey of 1913, described in its "Progress Report", January 16, 1914.
3. International Joint Commission survey of 1946-47 described in its "Report on the Pollution of Boundary Waters" 1951.
4. Routine sampling and testing of the lower river by the Detroit Water Board (Sewage Treatment Division) from 1938 to 1955.
5. Frank P. Coughlan, Jr., "Better Water Supply for Wayne County—Locating the New Intake", Journal Am. Water Works Assoc., May 1958.
6. Thomas, H. A. Jr., Statistical Analysis of Coliform Data, SIW 27:212 (1955).



COLIFORM DENSITIES AT SELECTED CROSS-SECTIONS, DETROIT RIVER.

DIGITAL COMPUTERS FOR PIPELINE NETWORK ANALYSIS^a

Discussion by John W. Hamblen
Closure by Quintin B. Graves and Don Branscome

JOHN W. HAMBLEN.¹—The authors have presented a useful description of some of the features and uses of digital computers. While the program which they have indicated for solving hydraulic networks may be useful, it does not provide for the most effective utilization of the IBM 650, particularly when the floating decimal device is available.

The writer has devised the program described below for the solution of hydraulic networks with the Hardy Cross method of iteration as a base. Larger networks may be analysed by this program than by that proposed by the authors.

Purpose

To determine the final flows, Q , and the corresponding head losses, H , in each pipe of a hydraulic network after a K -value and an assumed initial flow, Q , have been arrived at from basic information on pipe sizes, roughness, lengths, junctions, inflows, and outflows.

General Description

PHASE I loads the pipe identifications, K -values, and initial flows, Q 's, onto the drum and then proceeds to check the K 's and Q 's of pipes which are common to two adjacent circuits for keypunching and other errors. This could be extended to check for balance at junctions.

PHASE II then computes ΔQ for each circuit, stores them, and then adjusts the Q 's for each pipe. The program halts with 01 1097 9004 in the program register, the number of iterations = m in the upper accumulator, and $\text{Max } \Delta Q$ in the distributor. The operator displays $\text{Max } \Delta Q$ and if less than or equal in absolute value to a prescribed value, he proceeds to PHASE III by pushing computer reset and then program start. If $|\text{Max } \Delta Q|$ is greater than the prescribed value he continues to next iteration by pushing program start. The operator may set the Programmed switch to Run for any desired time interval and then reset to stop for the same checking procedure as described.

PHASE III computes the head loss, H , then punches pipe ID, K , final flow = Q , and H for each pipe.

a. Proc. Paper 1608, April, 1958, by Q. B. Graves and D. Branscome.

1. Associate Prof. of Math. and Director, The Computing Center, Oklahoma State Univ., Stillwater, Okla.

Note

A "pipe" occurs in the data twice if it belongs to two adjacent circuits. The following example as shown in Fig. 1 will serve to show how pipe ID's are determined: cccpp where ccc is circuit number and pp is pipe number within circuit number ccc.

Limitations

This program will handle a network of not more than 123 circuits with a total of not more than 520 "pipes" (see Note above). The floating decimal device is used throughout.

Mathematical Methods

The value of K must be computed for each pipe from the values of "K" per 1000 ft. (or otherwise) corresponding to each given roughness, pipe diameter, and pipe length. An initial estimate of flow, Q , must be determined for each "pipe" with the only essential requirement being that a "balance" exists at each "junction". The relationships utilized in this solution, which follows the Hardy Cross method of network analysis, are:

$$\frac{H}{Q} = K \cdot Q^{1.85}$$

$$H = KQ^{1.85}$$

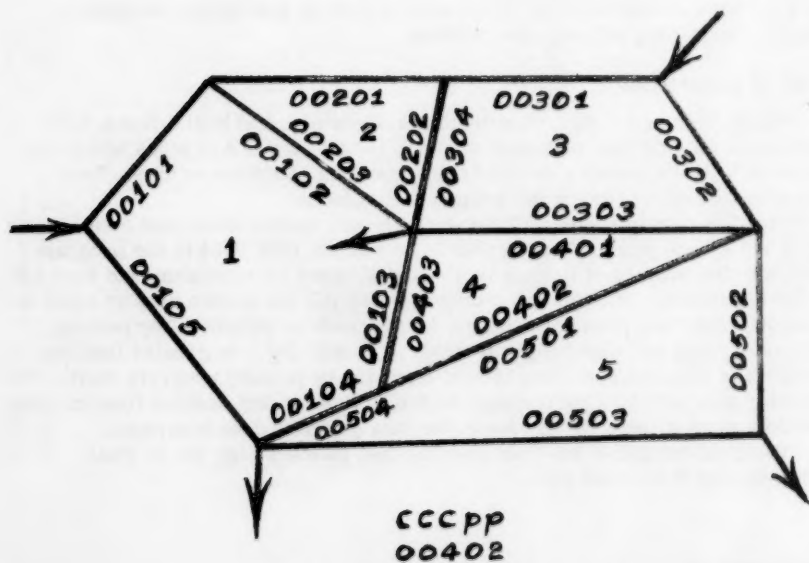


Figure 1

$$\Delta Q = - \frac{\sum KQ^{1.85}}{1.85 \sum KQ^{0.85}} \quad \text{for each circuit}$$

$$\text{Corrected } Q = Q + \Delta Q$$

Where:

H = head loss in any given pipe

Q = rate of flow

K = "K" x length of pipe

ΔQ is the correction to be applied to the rate of flow of each pipe in a given circuit.

$\sum KQ^{0.85}$ and $\sum KQ^{1.85}$ are sums of the respective products for each circuit.

The conventions given below are to be followed in setting up the computations:

1. Proceed around each hydraulic circuit in the system in a clockwise direction.
2. When proceeding with the flow K, Q, and H are positive.
3. When proceeding against the flow K, Q, and H are negative.
4. Summation H/Q, or $KQ^{0.85}$, is arithmetic.
5. Summation H, or $KQ^{1.85}$, is algebraic.
6. Sign of correction to Q, or ΔQ , is opposite to summation H sign.
7. Sign of ΔQ transferred to adjacent circuits is reversed.

Storage Requirements

			Locations
ID	-	Table	0000 - 0520
K	-	Table	0550 - 1070
Q	-	Table	1100 - 1620
ΔQ	-	Table	1620 - 1774

Subroutines (1n and e^x) 1775 - 1999

Program elsewhere on drum and all of IAS. Also drum addresses of the form xx48, xx49, xx98, and xx99 are utilized for instructions.

Data

Input Format: (8 - 10 non load) one card for each "pipe"

columns 1 - 10 "pipe" ID

columns 11 - 20 K

columns 21 - 30 Q (11-pch in column 30 if negative)

Output Format: Same as input except that H will be in columns 31 - 40.

Wiring

Load-cards from column 1

8 - 10 digit words in and out "C"

R⁺ not wired, RSU and PSU wired.

HYDRAULIC NETWORK ANALYSIS

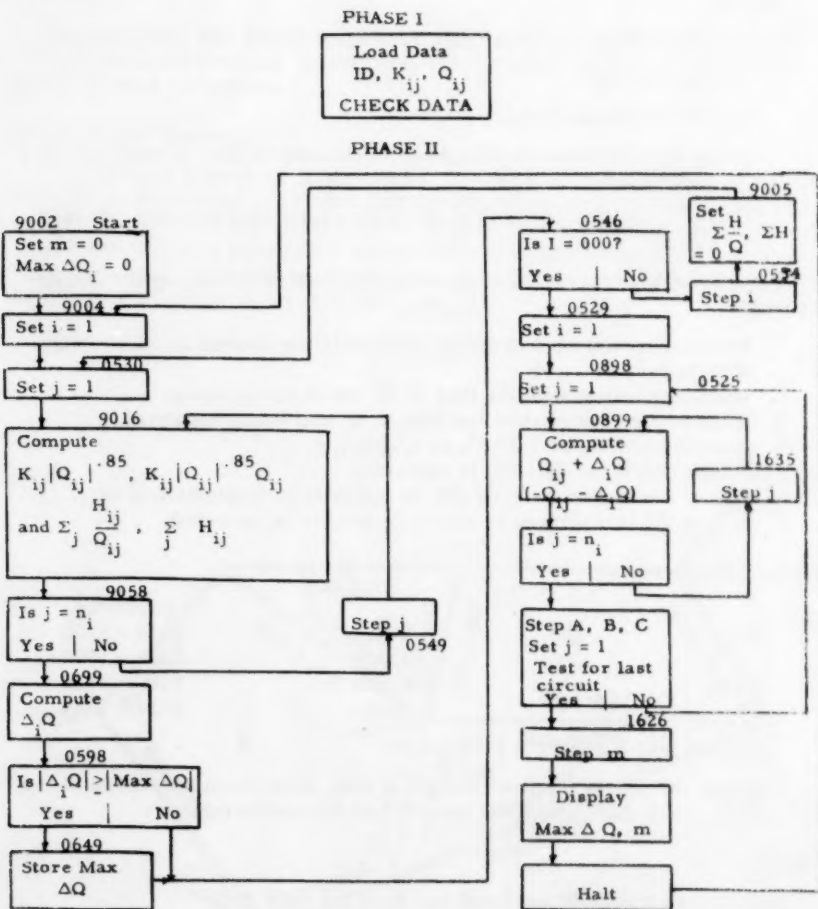


Figure 2

PHASE III

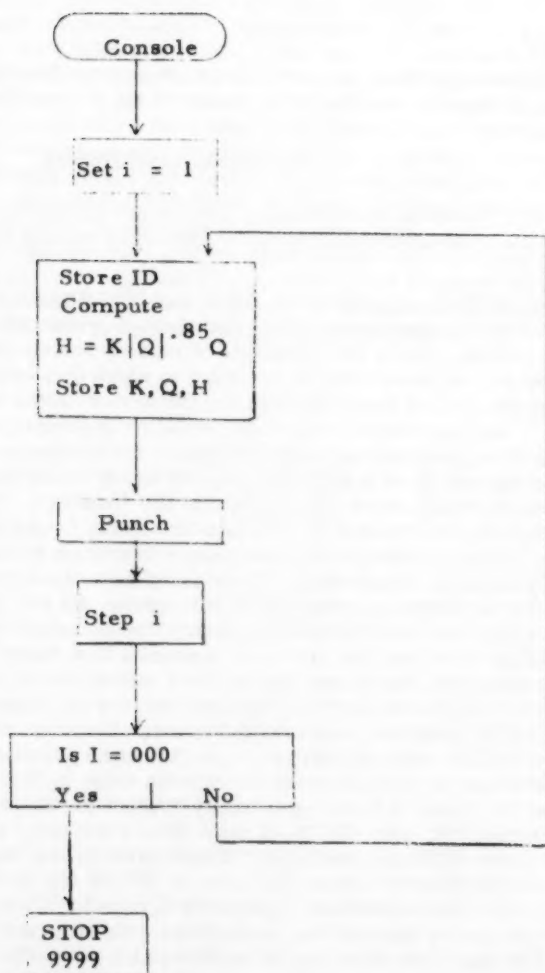


Figure 3

Equipment Specifications

650 plus 653 with floating decimal device, Index Registers, and Immediate Access Storage.

Testing

This program has been used with several small and medium sized systems. It is recommended that the user proceed with caution for maximum sized network.

Time

Approximately 1 sec. per pipe per iteration. The number of iterations required depends upon the initial values of the Q 's and the accuracy desired.

ACKNOWLEDGEMENTS

The writer is indebted to Dr. Graves for calling the problem to his attention and for describing the Hardy Cross method to him.

QUINTIN B. GRAVES,¹ M. ASCE and DON BRANSCOME,² J. M. ASCE. — The authors appreciate the fine discussions presented by Messrs. McPherson, and Radgiul, and by Mr. Hamblen. Points of interest which these discussions raise will be considered in the order in which they occur.

In the first of these discussions, the writers refer to "a hunting . . . effect . . .", with successive iterations, resulting in erratic, convergence of the final results in programs presumably written for electronic digital computers. This appears to be a difficulty with the Hardy Cross method. The digital computer, in itself, is not responsible for the "hunting". The authors have observed this occurrence in the use of the Hardy Cross method of network analysis. These characteristics are usually overcome by assuming a new flow distribution in the network. There would be no essential difference in the number of iterations required in this system and that of Hoag and Weinberg since they are both based on the Hardy Cross method of analysis.

While it is true that the initial, assumed flow rates require only a rough approximation, the closer the assumed values are to the correct values, the shorter will be the machine time and the less the chance of "hunting". It must be kept in mind that in assuming flows or otherwise the inflow at a junction must balance with the outflows from that same junction.

Perhaps the authors were not entirely clear in their use of the term " K ". However, Table 4 states specifically "Values of ' K ' for 1000 ft. of pipe . . ." A value of " K " (per 1000 ft. of pipe) from Table 4 for a given pipe diameter and Hazen-Williams coefficient is multiplied by the length of the pipe in thousands of feet to obtain the value of " K " for the particular pipe in question. This value is constant and if properly obtained will not be used thereafter for this particular pipe as long as the basic conditions are not changed.

The sign (flow direction) is accounted for primarily in the data on page 16. All K values are shown here as positive as the produce of K and $Q^{0.85}$ will

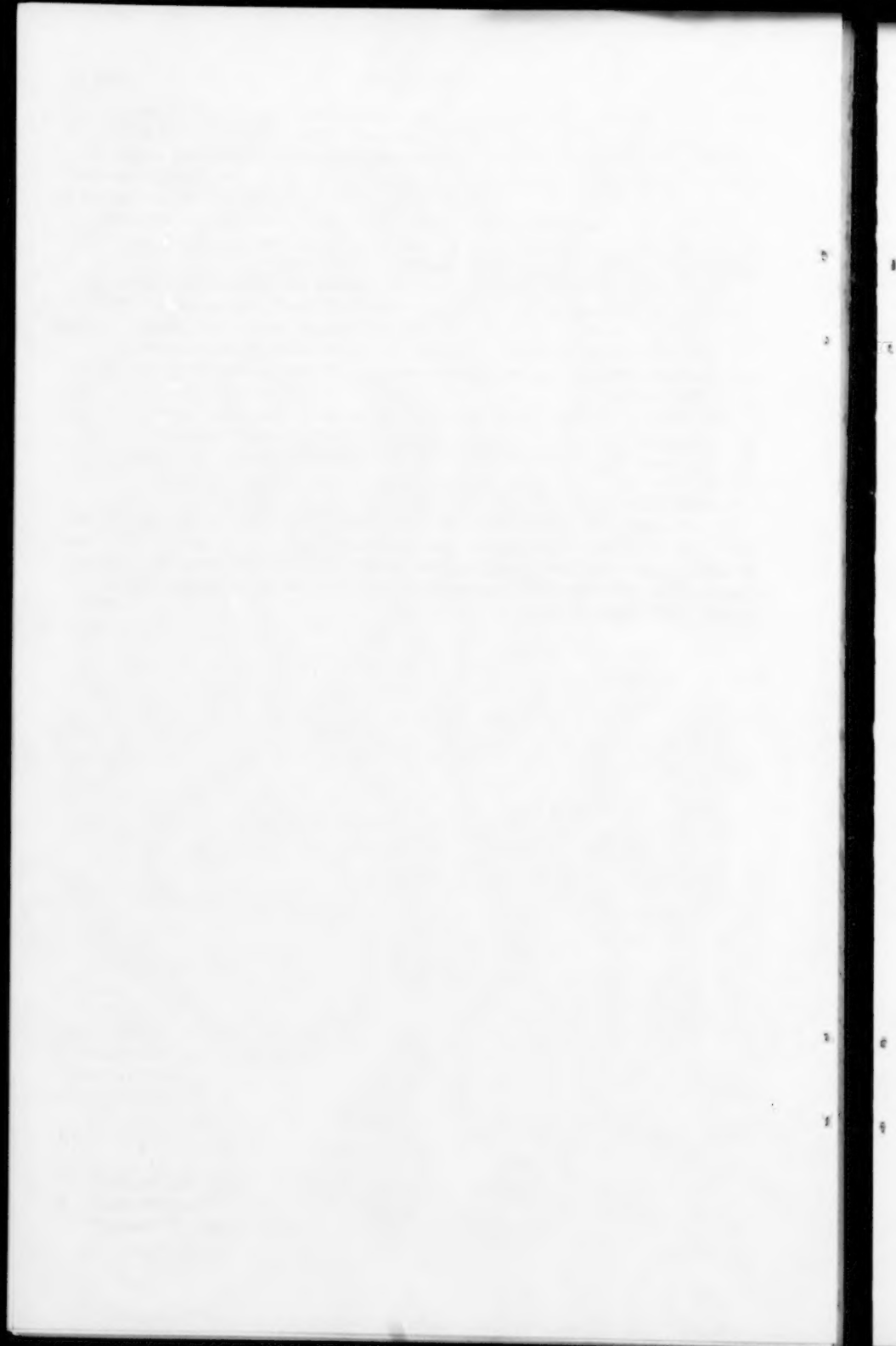
1. Prof. of Civ. Engr., Oklahoma State Univ., Stillwater, Okla.
2. Sales Engr., Aluminum Co. of America, Pittsburgh, Pa., formerly graduate student, Oklahoma State Univ., Stillwater, Okla.

always be positive. For this operation, the absolute value of Q is used so as to produce positive values of $KQ^{0.85}$, for each case. This value of $KQ^{0.85}$ is multiplied by Q with its proper sign in which case the values of $h = KQ^{1.85}$ will always have the same sign as stated in the Table 2. For computing the value of Delta ($\Sigma KQ^{1.85} / -1.85 \times \Sigma KQ^{0.85}$), the value $\Sigma KQ^{1.85}$ is multiplied by -1.85 . The plus and minus signs in the "program" tabulation as opposed to the "data" tabulation do not have a direct bearing on the sign convention of the Hardy Cross method but refer to machine operations.

One of the important aspects of the "K" values for pipes in a network is that each "K" expresses the combined effects of length, diameter and "C". Any combination of length, diameter and "C" values which will produce a given "K" value will have the same hydraulic effect on the network in question as any other combination of length, diameter and "C" values which produces the same "K" values.

One of the important points which the authors attempted to make in comparing analog (or McIlroy) computers with electronic digital computers is that the electronic digital computers are more readily available. Certainly, if the McIlroy analyzer were more readily available, its "visual" aspects would give it considerable advantage over the electronic digital computer.

Mr. Hamblen has presented a very fine program for use in connection with the solution of water distribution system flow problems. As stated in his discussion, larger networks may be handled with the IBM 650 using his program than would be possible with the program utilizing the Flops system as proposed by the authors.



ADVANCES IN SECONDARY PROCESSES OF SEWAGE TREATMENT
IN THE PERIOD OCTOBER 1, 1954 TO JUNE 1, 1957^a

Discussion by Gordon E. Mau

GORDON E. MAU,¹ A. M. ASCE.—Two basic points upon which the subcommittee report has touched, but about which more information is needed, deserve emphasis.

The differences in the hydraulic loading of trickling filters in England and the U. S. A. clearly demonstrate the need for data on the interrelationship between rate of BOD application, hydraulic loading, and size of filter media. It is known that a high instantaneous rate of water application—e.g., use of a fire hose—is often a practical method of removing excessive organic matter from a ponded filter. If ponding is not too severe, correction can often be obtained by holding a distributor stationary for a period of time over each section of the filter and thereby increase the local rate of application.

Because it was common practice in England to use rock as small as 1-1/2 inches in diameter, it is not enough to report that at Minworth, England, the optimum distributor speed was 15-30 minutes per revolution and that ponding occurred when the rotation time was 1-5 minutes per revolution. Because filters ponded when sewage was applied by distributors, as they are used in this country, there has been a change from small rock to sizes ranging from 2 to 3-1/2 inches in diameter and larger. However, using this larger rock with the intensive local high rate of application, as is accomplished with many distributors in England, results in overcoming ponding but at a decrease in filter efficiency. Thus, the important thing in discussing results is not only what is the hydraulic loading but what is it in relation to rock size and BOD loadings.

To further illustrate the differences in hydraulic loadings on trickling filters, the writer has observed that in England it takes about 12 minutes for several of the rectangular distributors to pass over the entire filter surface. On the other hand, in the United States it is a common requirement for a distributor to apply sewage to every section of the filter at least every 15 seconds. If a given amount of sewage is applied to two filters of the same area and depth and one distributor covers the bed in 12 minutes and the other distributor covers the bed in 15 seconds, it is clear that the instantaneous dosing rates—based on the area actually receiving sewage at any instant—vary by a factor of 48 but the average rates are the same. The high rate is necessary to maintain the voids in the small rock but it is undesirable when larger rock is used. Using the high instantaneous rate on large media results in less contact between pollutants in the liquid and active growth in the filter.

a. Proc. Paper 1612, April, 1958.

1. San. Engr., Ediger & Company, Wichita, Kans.

The writer observed that the rock size used in Germany is usually larger than that used in England but smaller than is common in present day American practice. Thus, the German practice of using deeper filters with relatively heavy BOD loadings, with little or no recirculation, is a further indication that the relationship between media size, BOD loading, and hydraulic loading is most important. Placing emphasis on just one of these features for a given filter can result in distorted, if not erroneous, conclusions.

Perhaps the optimum hydraulic rate of application could be determined for various media sizes and BOD loadings by performing extensive tests on filters constructed especially for a study. The filters would need to be large enough to accommodate rotary distributors for which the speed of rotation could be greatly varied. In addition, it would be desirable to have, say, four filters so the same size media could be tested simultaneously in each at 6, 9, 12 and 15 ft depths and under several combinations of unit volume BOD loadings and surface hydraulic loadings. Each filter would, of course, need its own secondary settling basin so the effects of recirculation could be adequately evaluated for each condition. Hydraulic loadings should be expressed as the instantaneous rate rather than the average rate. Upon completion of each series of studies, the media should be removed and replaced with another size so another series of experiments could be made.

The findings of such a study would have direct practical applications in addition to providing a sounder basis for theory in design. Good quality rock—e.g., large stones from washed river gravel—is available in some areas, but, media sizes commonly specified requires the importing of other rock at greater cost. In such cases, selecting a rock depth and an instantaneous rate of application which would permit use of local rock for filter media would be a direct economic benefit. Another economic benefit could result in some areas if the engineer could look to more than one source for filter media.

Regarding the introduction of air into activated sludge aeration basins, it is hoped that detailed information will be forthcoming in ASCE Proceedings on the efficiency and general results being obtained with large bubble aeration (no diffuser devices) which has recently been used in some German designs. This method of introducing air to aerators is considered to be economical and satisfactory for at least some applications in Germany. It differs greatly from our concept of fine bubble aeration and should merit more study in the U. S. A. so that if it has application here we need not be bound to the time honored method. Perhaps the modified system at Peoria, Illinois, is a step towards learning something about the use of large bubble aeration in the United States. However, it is quite probable that cross sectional shape of the aerators has a great influence in determining the effectiveness of large bubble aeration and studies should not be confined to aerators of one specific shape. Experiments in large bubble aeration will probably require prototype basins—rather than laboratory experiments—so that the full effect of surface aeration is realized.

SED RESEARCH REPORT NO. 19
SEWAGE TREATMENT BY LAGOONS^a

Discussion by John R. Thoman

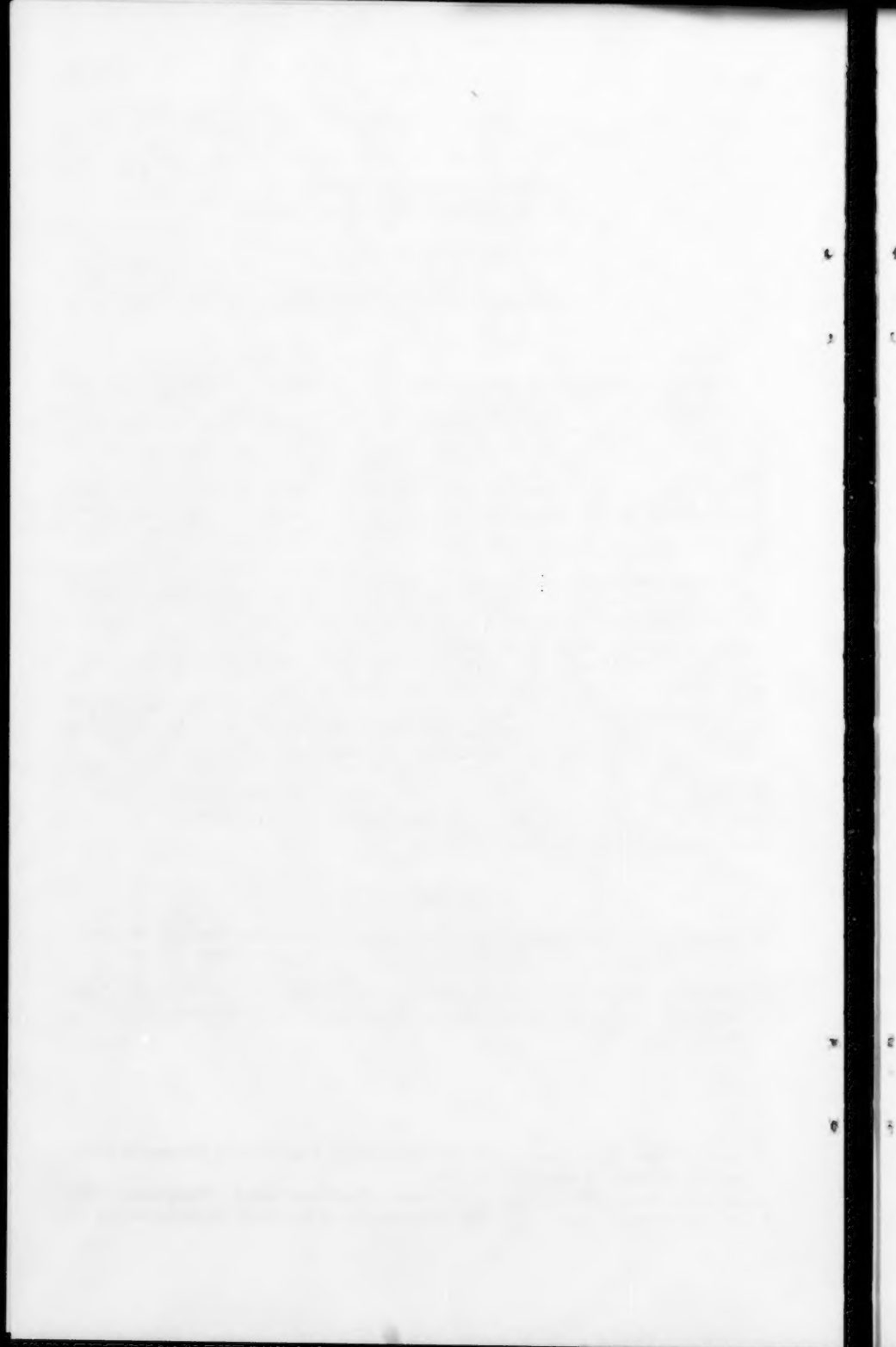
JOHN R. THOMAN,¹ M. ASCE.—Data from the 1957 Inventory of Municipal and Industrial Wastes Facilities⁽¹⁾—a cooperative activity of the State water pollution control agencies and the Public Health Service—show that lagoons are used in 631 plants serving 2,360,000 persons. In many cases lagoons are used in conjunction with some other secondary treatment unit; however, they are the principal treatment device in 430 plants serving 760,000 people. Detailed data by States, population size groups, and major drainage basins are available in a recently published summary⁽²⁾ of sewage works in the United States.

Of those plants where lagoons are the main secondary treatment process, almost 93 per cent are in communities of less than 5,000 population. Texas and California with 95 and 53 plants, respectively, report the largest number among the States, while the Missouri River basin with 123 plants has the greatest number among the major drainage basins. In the Colorado River basin 38 of 87 secondary treatment plants are lagoons.

Preliminary analysis of contract cost data for 88 lagoons constructed with financial assistance under the Federal Water Pollution Control Act (P.L. 660, 84th Congress) indicate an average cost, exclusive of land, of \$15.89 per capita in plants to serve 500 people, \$12.38 per capita for 1,000 people, and \$7.18 per capita for plants serving 5,000 persons. These cost data are expressed in August 1958 dollars when the Engineering News-Record Construction Cost Index stood at 764.4.

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- a. Proc. Paper 1678, June, 1958 by the Sanitary Engineering Research Committee, Sewage Treatment Section.
 1. Sr. San. Engr., Water Supply and Water Pollution Control Program, Public Health Service, Dept. of Health, Education and Welfare, Washington, D. C.



FRINGE AREA SEWERAGE PROBLEMS^a

Discussion by Harvey F. Ludwig

HARVEY F. LUDWIG,¹ M. ASCE.—As has been emphasized by Mr. Kiker, administrative history has proven that individual home septic tank systems should be considered at best as temporary expedients pending the installation of public sewers. Not that satisfactory systems cannot be designed for most cases—the writer's own experience indicates that properly-functioning systems can be designed for even the most difficult cases. The important point is that the relatively high cost of proper engineering design, together with the relatively high cost for the proper installation, are factors usually working against such propriety. The human factors involved in fringe-area development tend the opposite way, toward the installation in the individual homes of inadequate systems (usually with too little area for the leaching system). The administrative expectation, therefore, is that a good number of inadequate installations will occur in newly developing areas because the interests in saving costs tend to by-pass the element and concept of engineering design and supervision.

Mr. Kiker's emphasis on the need for more attention to the design of leaching systems is, again, certainly in tune with realities. Relatively speaking, too much attention has been given to how to shape and proportion the septic tank and far too little to the design of the leaching system. Within very wide limits, and given adequate volume, almost any shape of tank will suffice—a point long known to practitioners in the field. The leaching system, which is the critical component of the combined disposal works, has nevertheless received little if any research attention over the years, and only very recently has sanitary engineering thinking recognized that technological improvements will likely come from studies of the underground leaching phenomena more so than from studies of the niceties of tanks. Virtually nothing is known about the leaching phenomena—whether they are aerobic or anaerobic or both, to what extent a further degree of treatment is furnished by the aggregate in a trench, what is the significance of storage in a trench, whether the limiting factor in leaching is physical friction at the leaching surface or biological clogging, etc. The writer's opinion on the design of leaching systems, pending research to establish the scientific facts, is that most design criteria are over-concerned with the details of leaching systems (e.g., limiting the widths of trenches, allowing only partial credit for trench side-wall areas, etc.), whereas the really significant factor is the total amount of area provided which contacts permeable soil, regardless of whether this be horizontal or vertical

a. Proc. Paper 1714, July, 1958, by John E. Kiker, Jr.

1. Cons. Engr., Pres., Engineering-Science, Inc., 490 East Walnut St., Pasadena, Calif.

or a combination of both. The total area in the leaching system is comparable to the total volume of the tank—in neither case is there sufficient fundamental scientific information to justify much refinement in the system's shape and proportions. In the interim period, pending research findings to permit a better approach, the writer suggests the same credit be given to any square foot of area, horizontal or vertical or otherwise, contacting the same type of soil.

On the subject of package plants and units of the various types developed over recent years, it seems unlikely that such units can or will be made available which the householder can afford and which also will be trouble-free or involve no more operating complexities than within the householder's competence. There may be a field here for a household unit which can be regularly serviced, comparable to home water softening units which are regularly serviced by the agency making the installation. For larger problems, i.e., communities too small for conventional designs and where septic tank or lagoon systems are not feasible, the package plants are a constructive contribution and much credit is due those who have worked to develop them. With continuing development and improvement in their design and operation, it seems likely such plants will become generally recognized as one of the sanitary engineer's valuable "tools", acceptable in those places where it can give satisfactory results more economically than any other method.

PROPOSED CHANGES IN EASTERN WATER USE POLICIES^a

Discussion by Thomas R. Camp

THOMAS R. CAMP,¹ M. ASCE.—The author has brought to the attention of engineers east of the Mississippi River a movement favoring bureaucratic control of water resources which has gained a very considerable momentum during the past five years. This movement is now directed toward a replacement in the eastern states of the common law "Riparian Doctrine" of water rights with acts by each state legislature which would "establish a single state administrative agency charged with the development, use and control of all water resources of the state."

This movement, if successful, would lead to expropriation by a state of some or all water rights without just compensation, and it might lead to expropriation or at least control of some or all of the land since the land comprises the watershed of the streams and its use effects the flow in the streams. The author points out that "there may be considerable doubt as to the constitutional validity of taking water from a riparian owner without compensation and giving it to another permit holder." In the writer's opinion there is no doubt whatsoever that this constitutes a taking of private property without compensation and is therefore a violation of the Constitution.

Before relegating the common law doctrine of riparian ownership to limbo, it would be well to examine into its workings in the past. Is it really outmoded and, if so, to what extent? Who is it that finds it unworkable? Can it not be modified by legislative act to cover most, if not all, conditions?

During the past decade there has been a phenomenal increase in water demand in the eastern states for municipal and industrial purposes. There is no indication that these increases in normal demand cannot be met for many years in the future, except for the fact that the eastern farmer has suddenly been alerted to the value of irrigation during the growing season. This awareness by the farmer of the value of irrigation in the east is the direct result of a powerful promotional effort by one of the federal agencies. In taking water for irrigation, a consumptive use, the farmer is appropriating the water rights of downstream riparian owners without, we suspect, proper compensation. Under the common law doctrine, the downstream riparian owners have recourse to the courts; but, unfortunately, there are just too many farmers to sue and it will be difficult to prove under present law that they have injured downstream riparian owners.

The Riparian Doctrine has been a very strong factor in the development of the industrial northeast. The building of the City of Lawrence and the City of

a. Proc. Paper 1777, September, 1958, by Murray Stein.

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Lowell on the Merrimack River and the building of the City of Holyoke on the Connecticut River about 100 years ago, to cite a few examples, was done entirely by private individuals who had the foresight to recognize the value of water power rights at particular sites. Land and water rights were acquired by purchase. Canals and locks were constructed and the adjacent properties were sold to industries along with indentured water rights. These water rights are as much real property as the land itself.

In the development of municipal water supplies or power projects, the developer acquires the right by special legislative act. Under these acts a developer has been required to recognize riparian ownership and to pay claims for damages where such damages can be demonstrated. The present common law doctrine of "reasonable use" has developed over the years through the findings of the courts. This doctrine holds that every riparian owner is entitled to the reasonable use of the water flowing through his land provided it is not substantially decreased in volume or quality through such use.

One great merit of the riparian doctrine is that it is not necessary for the user to define what constitutes reasonable use before he enjoys such use. The burden of proof is placed upon the other riparian owners to demonstrate that they are damaged by such use. It is in the court actions resulting from damage claims that reasonable use in particular cases is defined.

In major water supply or water power developments the developer recognizes to start with that he must satisfy the other riparian owners. To this end he impounds sufficient water during periods of high runoff for release to downstream riparian owners during dry periods. The farmers on a watershed are no different from other riparian owners. They, too, can impound water during the periods of heavy runoff for their own use during the irrigation season and for release to the downstream riparian owners so as not to damage them. No change in the law is required for this purpose.

A number of eastern states have recently enacted laws to set up water resources commissions. In Massachusetts and in Connecticut the commissions are charged with the responsibility of studying water resource problems and recommending legislation if desirable. The report of the Connecticut Water Resources Commission to the 1957 General Assembly states that "Our riparian rights doctrine of laws presents a more flexible standard which is more readily adaptable to the extremely variable situations that exist in Connecticut than would a statutory appropriation or allocation system. The doctrine of reasonableness of use of water when considered with other uses being made of the same source appears to be best adapted for this state. The law can never be static and must change with the changing requirements of the state. This is a great advantage of the common law. . . . Statutory rules are far less subject to change in changing times."

One great defect in the common law doctrine of riparian rights is that it is limited to surface waters and does not recognize the fact that both surface and ground waters are flowing together from the boundaries of the watershed downstream to the outlet and are intermixed during the course of travel. There is no valid reason why the riparian rights doctrine cannot be extended by statute to include all waters on a watershed, both surface and ground.

The Water Resources Commission of Connecticut found in its 1957 Report that the Connecticut court has been presented with only two cases involving rights to the use of ground water. The court adopted, in 1850, the so-called common law or English rule of capture which had been formulated seven years previously by an English court. This rule allows a landowner to make any use

he desires of all the water he can catch under his land regardless of its interference with other landowners' uses of the water, although malicious and unduly wasteful actions would probably be prohibited. This rudimentary rule was adopted in most American states where ground water cases arose at an early date, but the rule has almost everywhere been modified in subsequent decisions by adoption of the so-called American rule of reasonable use. This latter rule prohibits a landowner's use of ground water elsewhere than on his overlying land if neighboring landowners would otherwise be injured.

It will be noted that the American rule of reasonable use of ground water will permit farmers to take substantially the whole dry weather flow of a watershed for irrigation purposes without compensating the downstream riparian owners for damages to their use. This is a real hazard to existing and new public and industrial water supplies. The issue can best be met by extending the riparian doctrine to include ground waters.

PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Pipeline (PL), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW), divisions. Papers sponsored by the Board of Direction are identified by the symbols (BD). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper numbers are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 1449 is identified as 1449 (HY 6) which indicates that the paper is contained in the sixth issue of the Journal of the Hydraulics Division during 1957.

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c. Discussion of several papers, grouped by divisions.

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